DDT

STANDARDS DEVELOPMENT BRANCH OMOE
3 6936 00000 1587

ONTARIO

DDT Residues in the Muskoka Lakes System

1972

SB
952
.D2
B64
1972
MOE

Date Due

SB DDT residues in the Muskoka
952 Lakes system / Boelens, R.G.V.;
.D2 Rumsey, C.R.
B64 4620
1972

Copyright Provisions and Restrictions on Copying:

This Ontario Ministry of the Environment work is protected by Crown copyright (unless otherwise indicated), which is held by the Queen's Printer for Ontario. It may be reproduced for non-commercial purposes if credit is given and Crown copyright is acknowledged.

It may not be reproduced, in all or in part, part, for any commercial purpose except under a licence from the Queen's Printer for Ontario.

For information on reproducing Government of Ontario works, please contact Service Ontario Publications at copyright@ontario.ca

3,0 Ont
3,00 MOE

SB
952.D2
B64
1972

Environment Ontario

DDT RESIDUES IN THE MUSKOKA LAKES SYSTEM

Report No.2 on a water
quality evaluation
program in the Muskoka
Lakes.

HAZARDOUS CONTAMINANTS
AND STANDARDS BRANCH
135 ST. CLAIR AVENUE WEST
TORONTO, ONTARIO M4V 1P5

By

R.G.V. Boelens

C.R. Rumsey

Biology Section

Ministry of the Environment

June, 1972

PREFACE

Continuing efforts have been underway since May of 1969 to assess the status of water quality throughout the Muskoka Lakes system. A first report outlining the nature of the overall program and providing the results of a water use survey was issued in July of 1971.

This report documents the results of assessments relating to the presence of DDT in the Muskoka Lakes. Higher than normal concentrations of this pesticide came to light as a result of earlier investigations and this report is an attempt to bring together all of the information obtained to date and to provide a foundation for necessary continued surveillance of the situation.

An additional report relating to the question of aquatic enrichment of the Muskoka Lakes is close to completion and will be distributed in the near future.

As of April 1st, 1972, the Ontario Water Resources Commission was incorporated within the new Ministry of the Environment whereas the Department of Lands and Forests became part of the new Ministry of Natural Resources. The major part of this report was prepared during the latter part of 1971 and the two government agencies are referred to by their former titles.

TABLE OF CONTENTS

page

SUMMARY.................................... 1

RECOMMENDATIONS.................................... 4

INTRODUCTION.................................... 7

Regulation and Use of DDT in Ontario.............. 12

Muskoka Lakes DDT Studies.................... 14

Past Use of DDT in the Muskoka Lakes Watershed.... 16

PROJECT OUTLINES.................................... 19

Collection and Analysis of Fish.................. 19

Lake Trout Fry Survival Study.................... 19

Collection and Analysis of Water, Sediments and Clams.................................... 20

TECHNICAL CONSIDERATIONS.................................... 25

RESULTS AND DISCUSSION.................................... 29

DDT in Fish.................................... 29

Lake Trout Fry Survival Study.................... 36

DDT in Water, Sediments and Clams................ 41

Magnification Factors............................ 58

Distribution of DDT Isomers and Metobolites....... 58

The Consumption of DDT Contaminated Fish.......... 61

page

REFERENCES.. 64

APPENDIX A

Processing and Analytical Techniques............ 66

APPENDIX B

Common and Scientific Names of Fish Species..... 68

APPENDIX C

DDT in Muskoka Lakes Lake Trout................. 69

APPENDIX D

DDT in Lake Trout and Smelts from Nine Lakes in the Muskoka Area................................ 72

APPENDIX E

DDT Levels, Lake Muskoka Fry Survival Study..... 73

APPENDIX F

DDT in Water, Sediment and Clams................ 74

LIST OF FIGURES

PAGE

Figure 1. Pesticide Cycling in the Environment..... 8

Figure 2. Muskoka Lakes Stations Monitored for DDT Using Caged Clams........................ 23

Figure 3. Principal Axes for the Correlations of Muscle-borne DDE with Weight of Lake Trout. Muskoka Lakes, 1966-1970......... 34

Figure 4. Principal Axis for the Correlation of Muscle-borne DDT in Lake Trout with Smelts. Muskoka Lakes 1966-1971......... 35

Figure 5. Ranges of Total DDT in Muscle, Gonad, Eggs and Fry of Ten Female Lake Trout from Lake Muskoka 1967 and 1968.......... 37

Figure 6. Mean DDT Levels in Clams, Muskoka Lakes Monitoring Program, May to October, 1970. 42

Figure 7. Mean DDT Levels in Wild and Caged Clams, Muskoka Lakes Monitoring Program, August to October, 1971......................... 49

Figure 8. DDT in Muskoka River, Inlet and Outlet, May to November, 1971.................... 51

Figure 9. Simplified Estimate of DDT Budget, Muskoka Lakes, 1971...................... 56

LIST OF TABLES

PAGE

Table 1. DDT in Muskoka Lakes Fish Muscle, Expressed as ppm DDE, Wet Weight, 1966 - 1971.............................. 30/31

Table 2. Total DDT in Water, Sediment and Clam Composites, Expressed as ppb, Muskoka Lakes, September,1971.................... 46

Table 3. Total DDT in Muskoka Lakes Water, Sediment, Clams and Fish, Expressed in Terms of Wet Weight, 1966 - 1971........ 59

Table 4. Mean Percent DDT Isomers and Metabolites in Water, Sediment, Clams and Fish, in the Muskoka Lakes, 1968 - 1971.......... 60

SUMMARY

1. The distribution of DDT in Muskoka Lakes fish is dependent on a number of factors including species, habitat, diet, longevity, size and fat content. Extremes are exemplified by the lake trout at one end of the spectrum and the white sucker at the other. Levels of DDT in lake trout have been positively correlated with weight for Lakes Muskoka, Rosseau and Joseph, and using the accumulation of DDT by this species as an index of contamination, Lake Joseph appears significantly less contaminated than the other two lakes. From 1966 to the present time, no significant reductions in DDT content of lake trout muscle were evident for any of the three lakes studied.

2. Good correlation was obtained between DDT levels in lake trout and smelts from nine lakes in the Muskoka area, suggesting that smelts, a major food item in the lake trout diet, may be an important vector in the transfer of DDT to the latter species.

3. Fry survival studies using lake trout from Lake Muskoka showed high mortality of fry on absorption of the yolk-sac which, similar to the findings of Burdick in New York State (1964), strongly suggest that declining reproduction may be a function of high DDT levels in the adults. Arguments are put forward to indicate that Lakes Rosseau and Joseph may be similarly affected, and that the DDT content of mature female lake trout must fall by at least 25% from the present levels before significant improvements can be expected.

4. DDT levels in water, sediments and clams of the Muskoka Lakes system showed marked variation with location, while seasonal changes were also evident in water and clams. Whereas the lower values in each case are within ranges established in other areas of Ontario with low incidences of DDT use, certain locations showed elevated levels indicative of continuing input of terrestrial residues derived from previous biting fly and forest insect control programmes. Greater significance is given to shoreline run-off in contrast to inputs from the Muskoka River watershed, and it is estimated that in 1971 the total DDT load to the system was approximately 113 lbs. It is felt that the use of caged clams offers a simple and efficient method of following trends in DDT contamination at locations where continuing inputs are suspected.

5. The knowledge that DDT breaks down slowly in the environment would, in itself, suggest that considerable time will be required for many species of Muskoka Lakes fish to achieve an acceptable level of DDT contamination. Furthermore, the recovery period will likely be prolonged by the cold benthic conditions of the lakes, accumulations of residues in the deeper portions, current inputs to the system and continuous recycling of residues among the biota.

RECOMMENDATIONS

1. Annual sampling and analysis of the smelt population in Lakes Muskoka, Rosseau and Joseph should continue for the next several years. In order that small changes in DDT content might be accurately detected, efforts must be made to achieve uniformity of size, location and time of capture. If possible, an early year class should be selected to determine any improvement at its onset. Fish may be composited, but at least 25 separate analyses should be performed for each lake. If no change in DDT contamination of smelts is noted over a two year period, annual sampling should be discontinued for at least two or three years.

   Earliest indications of improvement in fish might be obtained by regular examination of DDT levels in selected warm-water species from Milford Bay, such as the rock bass and white sucker.

2. As soon as definite signs of DDT depletion are evident in the smelt population, sampling of lake trout should be undertaken as outlined above, to determine the existence of an analagous trend in this species. When DDT levels in the muscle of mature females are consistently below 20 ppm, a fry survival study should be undertaken, including control fry from uncontaminated areas.

3. All fish data obtained should be examined for changes in the ratio of p,p' DDE to p,p' DDT and p,p' DDD.

4. Stocking of two-year-old lake trout should be continued for the following reasons:

    a. to maintain an adequate number of lake trout in the system pending the reappearance of a self-sustaining lake trout population

    b. to maintain a sufficient population of lake trout to provide adequate samples of fish for DDT analysis and some angling.

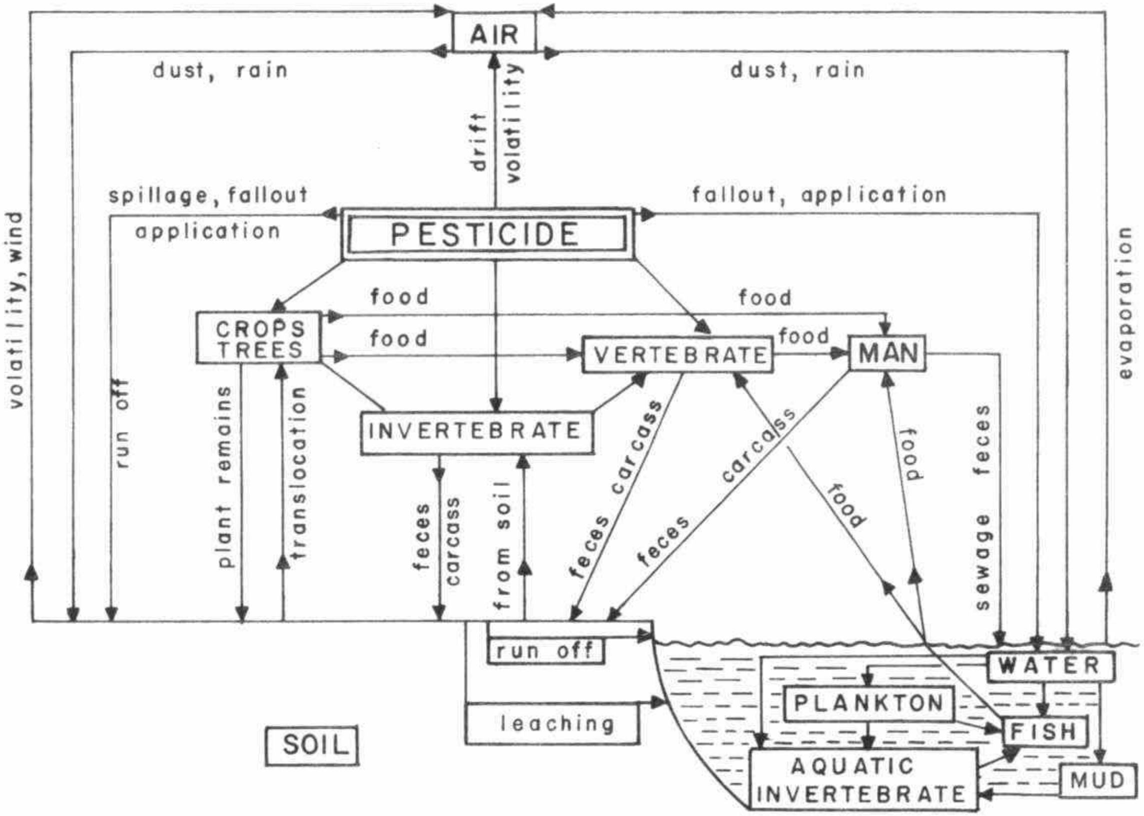
5. Each spring, groups of clams (*Elliptio complanata*) should be placed in containers with sediment which has a low DDT content (1 ppb), and located in shallow water at Milford Bay in Lake Muskoka. Control stations should be established at Sandy Bay and at a similar location in a neighbouring uncontaminated lake. Clams should be collected and analysed during times of peak feeding such as June or July.

6. A census of sport fishermen in the Muskoka Lakes area should be undertaken at the earliest opportunity to determine consumption levels for lake trout, whitefish and cisco, in order to ensure that these are within safe limits as determined by the Provincial Department of Health.

INTRODUCTION

Over the past ten years a considerable body of information has appeared in the scientific literature concerning contamination of the aquatic environment with various persistent pesticides. The advent of reliable and sensitive analytical techniques was undoubtedly a major factor in this regard, although worldwide concern for the welfare of fish and other aquatic life has provided the main impetus for such investigations. Evidence is mounting to indicate that many insecticides, notably a class of persistent chemicals known as chlorinated hydrocarbons, will not always remain at the site of application but may be transported from the land to the water through the action of wind and water erosion (Figure 1). As a result, many lakes and reservoirs have become depositories for insecticide residues which may ultimately be incorporated into the tissues of aquatic organisms. Although amounts of insecticide present in the water or sediment tend to be minute, levels in predatory fish and waterfowl may be substantial. The explanation is to be found in the ecological relationships which exist between organisms comprising the aquatic community, since the transfer of material through the food chain results in progressive accumulation of residues with increasing size and

FIGURE: I PESTICIDE CYCLING IN THE ENVIRONMENT



FROM EDWARDS (1970)

complexity of the organisms (Macek and Korn, 1970). Thus the concentration of a particular contaminant in microscopic, single-celled plankton may be several times greater than that found in the water, while the corresponding level in a plankton-grazing fish may be several hundred times the concentration in the water.

It is disconcerting to note that in the majority of instances where insecticide contamination has been identified, little or nothing is known of the biological implications of the residues. Although many pesticides are acutely toxic to aquatic fauna at low concentrations in water, relatively high levels may be accumulated by the tissues without producing any obvious effects. Except in cases of accident or misuse, pesticides in the aquatic environment seldom achieve acutely toxic levels, and without the use of sophisticated analytical techniques their presence would often go unrecognized. However, it is now known that tissue-borne residues of certain insecticides may upset the reproductive processes of predatory fish and fish-eating birds so that the numbers of viable offspring are significantly reduced (Burdick 1964; Hickey et al 1968). Such effects are extremely difficult to detect, but may be more devastating to the population in the long term than a series of direct mortalities related to acutely toxic conditions.

Burdick examined the occurrence of the insecticide DDT and its derivatives in lake trout, their eggs and offspring from a number of lakes in New York State, where heavy applications had been made over the surrounding terrain to control the gypsy moth, black fly and mosquito. Heavy mortality was reported amongst the fry when DDT in the ether extract of the eggs achieved 2.9 parts per million (ppm) or above, and it was felt that this finding explained the serious losses of fry experienced by the Lake George Hatchery between 1955 and 1958.

It was quickly apparent to fisheries personnel in Ontario that there were a number of important similarities between the situation in New York State, and that in the Muskoka Lakes District of Southern Ontario, where DDT had been extensively used since the early forties to control biting flies and to combat outbreaks of the forest tent caterpillar.

Prior to the late fifties, lakes Muskoka, Rosseau and Joseph supported an excellent sport fishery for lake trout (Salvelinus namaycush). By the year 1960 the Ontario Department of Lands and Forests had received a number of complaints from sport fishermen which indicated a decline in angling quality for this species in Lake Muskoka. This was in spite of the fact that natural fish populations had been supported by extensive government plants of four to five inch yearling lake trout up to that time.

A netting survey conducted by Department of Lands and Forests personnel in 1960, confirmed suspicions that lake trout were not abundant, and that few if any young of that species were present. It was also apparent from the survey that there had been a dramatic increase in numbers of the American smelt (Osmerus mordax) which were introduced to the Muskoka system in the early fifties. It was speculated that this proliferation of smelts may have been, in part, responsible for the reduction in lake trout numbers. The possibility of damage to the fish population by pesticides had not been considered until 1964 when the results of Burdick's work were released.

The findings of Burdick in New York State, the high incidence of DDT use around the Muskoka lakes and the concomitant decline of the lake trout in this system, provided strong circumstantial evidence of reproductive failure due to DDT contamination. Investigations carried out by the Ontario Department of Lands and Forests between 1966 and 1968, utilizing analytical facilities of the OWRC, provided data supporting this contention, and also raised the question of the suitability of several fish species for human consumption. This information played an important role in bringing about legislative controls over DDT use in Ontario early in 1968.

Regulation and Use of DDT in Ontario

The insecticide DDT, while relatively inexpensive to manufacture, has the ability to control a vast array of insects, and through its resistance to degradation may subdue insect populations for extended periods of time in contrast to less stable compounds. Understandably, such features combine to produce a pesticide with widespread applications ranging from the protection of fruit, vegetable and tobacco crops to the control of biting flies and forest insect pests. In Ontario, significant use of DDT was made for all these purposes up until 1966, when action was taken by both the Department of Lands and Forests and the Ontario Water Resources Commission to discontinue the use of DDT in biting fly control programmes. By the end of the 1967 summer season, the Department of Lands and Forests had discontinued the use of DDT in all of its programmes while the Department of Health had introduced a requirement under the Pesticides Act making permits mandatory for all applications made by aircraft, concentrated air blast machine and power duster. From 1967 to 1969 inclusive, a large number of recommendations for DDT use were deleted from the Ontario Department of Agriculture spray calendars, and in the latter year the Pesticide Act was again modified to limit future uses to a) bat extermination, b) cutworm control on tobacco crops and c) plant bug extermination on apples. Applications in all these categories are by permit only, and permits for other applications of DDT will not be issued unless an emergency has arisen or the public interest so dictates.

The reasons for implementing controls on continued use of DDT were outlined initially in an 'Interim Report on the Control of DDT Use in the Province of Ontario', issued by the Advisory Committee on Pollution Control in March, 1969. This report was designed primarily to assist the government in its deliberations concerning necessary controls over DDT, and was not widely distributed since it raised a number of contentious issues which could only be resolved pending the results of additional research. The Committee recognized the ubiquitous distribution of DDT residues in food products and wildlife, and relayed the viewpoint of the Occupational Health Division of the Department of National Health and Welfare that the presence of a biologically-active chemical such as DDT in the body fat of exposed individuals must be considered undesirable, if not dangerous. The report indicated however, that evidence was lacking to show that DDT had adversely affected the health of Canadians and that, despite the high concentrations found in fish from the Muskoka lakes, no direct evidence existed to show that levels occurring in Ontario waters had adversely affected fish. Nonetheless, alternatives to the use of DDT were available in many cases and the Committee recommended the development of programmes limiting its use wherever 'acceptable and economic'. It was also advised that monitoring and research programmes be continued and expanded where necessary.

Six months later, a more detailed account of the history, properties and side effects of DDT, entitled 'A Report on the Use of DDT in the Province of Ontario', was prepared by the Pesticides Advisory Board of the Ontario Department of Health. Two statements appearing in the summary of the latter report embodied the major points of concern. Namely, that evidence now existed to show that, because of its long persistence, DDT could become incorporated into food chains and also, that accumulations of this compound could adversely affect fish-eating birds and predatory fish. The changes made in the Pesticide Act in 1969 followed directly from the recommendations made in this report.

Muskoka Lakes DDT Studies

The 'Interim Report on the Control of DDT Use in the Province of Ontario', tabled in the Legislature in March 1969, contained as an appendix, a report from the OWRC prepared in 1967, concerning the accumulation of DDT in fish from the Muskoka Lakes system. The work was undertaken in 1966 and 1967, and involved the collection and analysis of lake trout and whitefish from Lake Rosseau and lake trout from Lake Muskoka. This survey, which utilized the resources of both the OWRC and the Department of Lands and Forests, was intended to provide preliminary data on the magnitude of DDT contamination in the sport fish populations of the Muskoka Lakes, so that the results might be considered in the light of knowledge from other sources. Whereas the high levels discovered suggested that natural reproduction of the lake trout might be seriously affected, no conclusive evidence for this was available at the time the report was prepared. However, it was indicated that fry survival studies were currently underway to evaluate the effects of DDT in lake trout eggs on the fecundity of this species. In addition, the report emphasized the need to ascertain the DDT contents of different groups or organisms representing various trophic levels in the Muskoka Lakes, since a better knowlege of the transfer mechanisms involved might lead to an estimate of the expected duration of the problem. Finally, the report called for the judgement of a competent medical authority to decide the acceptability of contaminated fish for human consumption and for the establishment of appropriate residue tolerances for the more commonly used or hazardous pesticides in fish.

This report describes the work completed by the Ontario Water Resources Commission and the Department of Lands and Forests, relative to DDT in the Muskoka Lakes, since preparation of the 1967 'Preliminary Report'. In response to suggestions contained in the latter document, sampling and analysis of lake trout and other fish species were greatly expanded during the period 1968 to 1970, fry survival studies were completed on lake trout from Lake Muskoka in 1968, whereas attempts to obtain data on plankton, bottom fauna and aquatic vegetation were largely unsuccessful. Additional work was undertaken to determine regional differences in DDT contamination within the Muskoka Lakes system utilizing clams as an indicator, so that suitable areas could be selected for monitoring future trends in DDT levels. The data collected from these various projects are discussed in the light of information concerning the status of the Muskoka Lakes sport fishery, and suggestions are offered for further investigations.

In order to provide some background information on the history of DDT use in the Muskoka Lakes watershed the following account is provided.

Past Use of DDT in the Muskoka Lakes Watershed

A recent investigation was undertaken in an attempt to examine the nature of DDT use in the Muskoka Lakes area. Information was acquired from the Ontario Department of Lands and Forests and the Ontario Department of Health, as well as numerous commercial pesticide applicators.

It has been determined that the use of DDT for land applications in the Muskoka area occurred as early as 1940, whereas treatments were discontinued as a result of government action in 1967. The chemical was applied to private lands exclusively in order to control biting fly populations as well as sporadic outbreaks of the forest tent caterpillar. Summer residents, resort owners and golf course proprietors were among the major DDT users.

Most of the large scale insect control programs were undertaken by commercial pesticide applicators utilizing float planes as well as land based aircraft. Some ground spray equipment was also involved, and no doubt many small applications were made by hand.

An estimate of the total amount of DDT used in the area is not possible since no permits were required for its application to land, and OWRC files show that no permits were issued for control of aquatic larvae. In view of the lack of government records, and in order to gain some insight into quantities used, a number of commercial pesticide applicators were contacted. Only two enterprises indicated that they had ever used DDT in the Muskoka area, while others said that they employed the insecticides Baygon, and possibly Baytex, rather than DDT. Since Baygon was much more costly than DDT at the time, there may be some room for doubt in this regard. However, two representatives indicated that Baygon provided more effective and lasting control than DDT against forest insects.

Of the two applicators who did use DDT, applicator 'A', who feels that he may have been the only one involved in the early years (prior to 1954), has no records of his spray programs. Applicator "B", who apparently used the largest quantities of DDT in recent times (1963-1967) has detailed records. These indicate that his personnel applied approximately 2000 lbs of 100% active DDT to some 10,000 acres of land in the Muskoka Lakes watershed.

Since there is no evidence of any agency having used this insecticide between 1954 and 1962, it is possible that some major contributors may have been overlooked. It is known that at least one commercial applicator, who was reported to have practiced forest insect control, is no longer in business and efforts to contact him were unsuccessful. The problem of estimating total DDT use in the vicinity of the Muskoka Lakes is further compounded by the likelihood that large amounts were applied privately in small scale applications.

PROJECT OUTLINES

Collection and Analysis of Fish

Fish analyzed for DDT content were netted by Ontario Department of Lands and Forests personnel during the years 1966 through 1971. Collections were made from a variety of locations throughout the Muskoka Lakes system, but only fish which were taken from the lakes themselves are represented in this report. Those captured from inlet and outlet waters were not included in the tabulations since sufficient evidence was not available to confirm that these specimens were representative of the lake populations.

DDT analyses were performed by both the OWRC (1966 and 1967) and the Provincial Pesticides Residue Testing Laboratory of the Ontario Department of Agriculture and Food, at Guelph. (1968 - 1971).

Fry Survival Study

This study was conducted using eggs from ten large female lake trout taken from Lake Muskoka in November 1967. Eggs from each female fish were fertilized using male fish from the same source, and each egg lot was incubated separately at the Wiarton Provincial Fish Hatchery. From each parent, samples of muscle and gonad, as well as fertilized eggs were submitted for total DDT analysis.

The egg lots were hatched in January 1968, and in early May, prior to the critical period of yolk-sac absorption, random samples of fry were collected and analyzed for DDT. Throughout the critical period the extent of mortality was recorded and dead fry were reserved for DDT determinations at a later date. In July, samples of the survivors from each egg lot, which were apparently healthy, were submitted along with the dead fry for analysis. Total DDT levels in muscle, gonad and fertilized eggs were determined by the OWRC laboratories, while fry were analyzed at the Pesticide Laboratory in Guelph.

Collection and Analysis of Water, Sediments and Clams

The amount of pesticide occurring in water at a particular time and location will be influenced by many factors including rainfall, current and wave action, absorption and release by the flora and fauna, nature of the bottom sediments and of course, the extent of recent pesticide use in and around the water body. For these reasons, chemical analyses of water samples obtained at a single point in time are often unreliable as an index of recent conditions. Composite samples taken over an extended period are more satisfactory but require expensive equipment or considerable field time.

Divers preparing to
collect clams for
DDT experiments.
Sandy Bay, Lake
Muskoka. 1970.

Weighing and
measuring clams
prior to caging.
Lake Muskoka DDT
program. 1970.

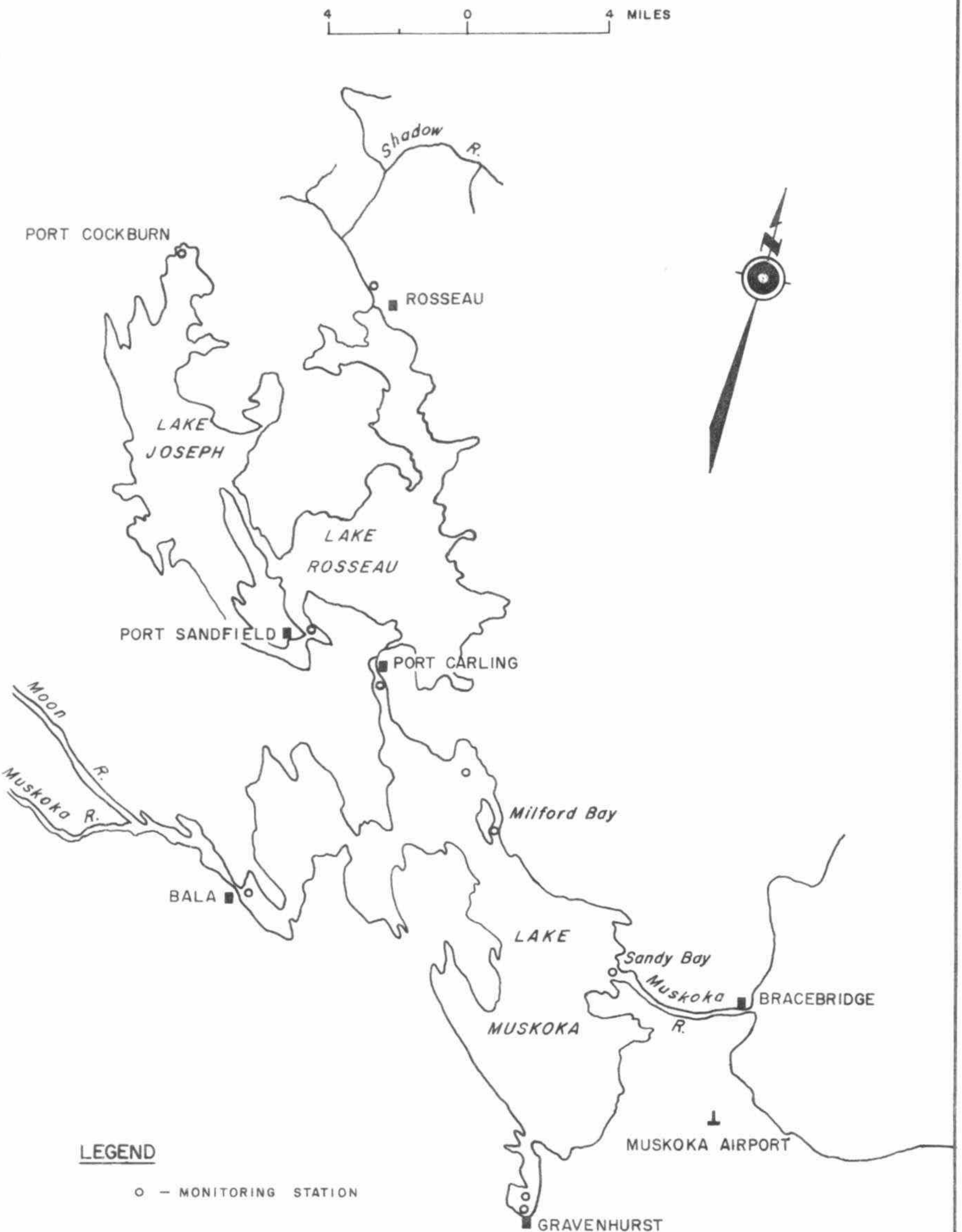
The clam is one of the few invertebrates in the Muskoka Lakes which is available in quantity at all seasons of the year and which has sufficient soft parts to permit analysis of individuals or small composites for DDT residues. When feeding, a steady flow of water is maintained across the gill filaments which selectively remove minute planktonic organisms and organic debris from the water and channel them into the mouth. Since water-borne residues of DDT are primarily associated with organic material, the clam might be expected to reflect seasonal and regional differences in amounts of DDT occurring in the water over its immediate past. Bedford et al (1968) showed that DDT levels in clams located in river situations reached an equilibrium with the environment after six weeks, and that levels in clams were highest at locations where water residues were highest.

As a result of these findings it was decided to test the suitability of clams for monitoring DDT inputs to the Muskoka Lakes system, and for recording residue levels of selected in-shore stations. In late May of 1970, wild clams were collected from Sandy Bay in Lake Muskoka and placed in cages at the mouths of the Muskoka and Shadow rivers in order to monitor major inputs. Stations near Port Sandfield and Port Carling were selected since they are located on waterways connecting the lakes, while Bala was chosen because of its proximity to the outlet for the entire system (Figure 2). At all locations, five clams were placed in each of five wire cages on the lake or stream bottom, at depths of four to fifteen feet. Three groups consisting of five Sandy Bay clams were promptly analyzed for DDT residues in order to establish background levels at the collection site. The majority of specimens used in this study were of the species *Elliptio complanata*. At monthly intervals up to the end of October one cage was removed from each location and the clams were submitted to the OWRC laboratories for DDT analysis.

Owing to the intervention of other work priorities, continuation of this program was not possible until the fall of 1971 when Sandy Bay clams were caged at ten locations including the five monitored the previous year. One of the additional locations, Port Cockburn, is situated on the northern margin of Lake Joseph, while the sites in Milford Bay and Gravenhurst are in Lake Muskoka. Port Cockburn, being in one of the more remote regions of the Muskoka Lakes was selected as a control station, whereas Milford Bay and Gravenhurst Bay are notable for their human population densities and there is a high possibility of past DDT usage in these areas.

In October of 1971, a large collection of Sandy Bay clams was obtained to better establish the inherent variability of DDT levels at a single location.

FIGURE: 2 MUSKOKA LAKES STATIONS MONITORED FOR DDT USING CAGED CLAMS 1970 – 1971



Commencing in May, 1971, water and sediment samples were procured at intervals throughout the summer from the Muskoka River at its point of entry into Lake Muskoka, and from the outlet just downstream of Bala. In September, additional samples of sediment and water were obtained from several stations where clams were caged, so that comparisons could be made between DDT levels in all three media. Collections of wild clams were made at some stations to determine differences between DDT levels in established populations and clams caged for relatively short periods of time. Analyses on sediment and water were performed by the Canada Department of Agriculture Research Institute in London, where researchers are currently involved with a program to compare pesticide contamination in waters draining agricultural, municipal and recreational areas.

TECHNICAL CONSIDERATIONS

DDT is an abbreviation of the chemical name dichloro-diphenyl-trichloroethane. The compound is normally marketed as technical grade DDT containing at least 70% of the p,p' isomer with the remainder as the o,p' isomer. Trace quantities of the metabolites p,p'DDE and p,p'DDD may also be present. DDT is practically insoluble in water, but has a high solubility in animal fats. Its stability in the environment is well illustrated by evidence which shows a half-life in soil of up to 12 years.

Since p,p'DDE and p,p'DDD appear to be the major products of breakdown in the environment, recent analyses performed on sediment, water and biological material include determinations on these two metabolites as well as the isomers p,p'DDT and o,p'DDT. However, some of the earlier data shown in the report were produced by an analytical technique involving the destruction and disappearance of p,p'DDD and o,p'DDT, and the conversion of p,p'DDT to p,p'DDE. As a result many of these early analyses were reported as p,p'DDE. Since the precise quantities of p,p'DDD and o,p'DDT destroyed in this procedure cannot be calculated, and since recent results include levels of both isomers and metabolites, it was decided to alter the latter in order to make them comparable to 1966 and 1967 figures. This was accomplished by subtracting o,p'DDT and p,p'DDD from the total DDT complex for all recent fish and gonad determinations, and expressing the result as p,p'DDE. Thus the values utilized in Table (1) and Figure (3) must be regarded as minimal. On the other hand, the data appearing in Figure 5, illustrating results of the fry survival study, and Table 3 which summarizes all the analyses referred to in the report, are expressed as 'total' DDT, and in the latter case it was necessary to increase the early analyses by applying an estimated correction factor of 15%.

As stated in the introduction, efforts to obtain data on various species of bottom fauna, plankton, vegetation and water during the 1969 summer season were unsuccessful. The chemists found that the small quantities of DDT which appeared to exist could not be separated from various interfering compounds, with the result that no reliable data could be produced. Similar problems were not experienced with fish samples having relatively large quantities of DDT. The discovery that certain compounds, known as PCB's (polychlorinated biphenyls), may interfere with the analysis of DDT on the gas-liquid chromatograph, raises the possibility that traces of PCB may have accounted for the difficulties experienced with the Muskoka Lakes samples. PCB's are synthetic compounds, widely used in industry, with chemical and biological properties similar to DDT. Foremost among the latter is the tendency for accumulation in animal fat deposits.

In addition, PCB's are highly persistent and may be readily transported through the environment by wind and water.

Since the history of PCB contamination in the environment is not well known, and analytical procedures for isolating these compounds are relatively new, it is possible that some portions of almost all the results mentioned in this report are, in fact, the product of PCB interference. However, to justify the comparisons of data which have been made it has been assumed that such interference constituted a small and consistent percentage of each figure. No interferences were apparent during recent analyses on water sediments and clams.

Three separate agencies were responsible for performing the analyses referred to in this report. The OWRC laboratory in Toronto undertook most of the pre-1968 determinations, whereas the Provincial Pesticide Residue Testing Laboratory in Guelph, performed the majority of fish analyses since that time. Water and sediments were analyzed by the Research Institute, Canada Department of Agriculture and Food in London, Ontario while all clam samples were examined by the OWRC laboratories.

Both the Toronto and Guelph laboratories have made various modifications and improvements to their procedures since the late sixties, but no attempt has been made to record these changes in the report. Brief outlines of the methods currently employed by all three agencies involved will be found in Appendix A.

RESULTS AND DISCUSSION

DDT in Fish

Table 1 summarizes all analyses performed on fish between 1966 and 1971. On examining the total picture, it becomes evident that considerable differences in DDT content exist between the 13 species represented. However, closer inspection suggests that several important biological and environmental factors might account for such variations. The most evident relationship is between high DDT levels and those species which frequent the deeper and colder regions of the lakes, and which can thus be separated from those fish inhabiting the shallow, warmer water during the summer months. Within these broad categories, it is further apparent that position in the food chain, longevity, size and fat content are all important factors in determining the degree of DDT accumulation by individual species. Although certain anomalies appear to exist, the situation may be well illustrated by the lake trout at one end of the spectrum and the white sucker at the other. The lake trout frequents cold water, is a renowned predator, may live up to 20 years and has a high (mean of 12.9%) fat content. The white sucker prefers warmer water, is not piscivorous, rarely achieves a lifespan of 10 years and has a relatively low (mean of 1.3%) fat content. It is hardly surprising to find that the mean level for DDT in suckers (0.5 ppm) is one fiftieth

Table 1: DDT IN MUSKOKA LAKES FISH MUSCLE, EXPRESSED AS ppm DDE, WET WEIGHT, 1966-1971

	Range Percent Fat		LAKE MUSKOKA				LAKE ROSSEAU				LAKE JOSEPH			
	Max.	Min.	No. Samples	Max.	Min.	Mean	No. Samples	Max.	Min.	Mean	No. Samples	Max.	Min.	Mean
COLD-WATER SPECIES														
American smelt	12.7	1.1	39	11.4	0.51	1.9	6	3.5	1.0	1.8	8	1.8	0.37	0.94
Burbot	3.5	0.81	3	0.52	0.36	0.44	1	-	-	0.68	1	-	-	0.15
Lake trout	32.3	0.31	66	115.0	1.9	35.1	49	49.4	2.3	23.2	66	49.4	3.0	17.0
Lake trout gonad-male			40	21.4	0.09	4.2	33	91.4	0.34	5.6	31	21.0	0.13	2.5
Lake trout gonad-female			29	44.5	3.6	11.0	20	22.4	1.7	6.4	34	13.6	0.37	4.5
Lake whitefish	11.9	0.58	8	38.5	5.8	20.9	10	22.4	1.6	8.9	7	9.2	0.37	3.9
Shallow-water cisco	17.5	1.4	1	-	-	10.9	7	7.3	1.0	3.1	30	9.7	1.0	3.7

Table 1: (continued) DDT IN MUSKOKA LAKES FISH MUSCLE, EXPRESSED AS ppm DDE, WET WEIGHT, 1966-1971

	Range Percent Fat		LAKE MUSKOKA				LAKE ROSSEAU				LAKE JOSEPH			
	Max.	Min.	No. Samples	Max.	Min.	Mean	No. Samples	Max.	Min.	Mean	No. Samples	Max.	Min.	Mean
WARM-WATER SPECIES														
Brown bullhead	2.9	1.2	-	-	-	-	2	1.2	0.87	1.0	7	0.84	0.08	0.36
Muskellunge	2.7	1.2	-	-	-	-	3	3.0	1.6	2.1	-	-	-	-
Pumpkinseed sunfish	2.7	2.1	5	0.60	0.14	0.33	-	-	-	-	-	-	-	-
Rock bass	2.8	0.19	15	0.63	0.14	0.32	11	0.39	0.04	0.20	3	0.18	0.04	0.09
Smallmouth bass	5.8	0.53	8	6.8	0.13	1.3	10	1.9	0.39	0.92	6	0.58	0.17	0.36
White sucker	2.4	0.36	20	1.6	0.05	0.33	11	0.64	0.07	0.25	17	4.1	0.05	1.03
Yellow perch	17.6	0.2	14	1.9	0.10	0.49	4	0.55	0.18	0.35	-	-	-	-
Yellow walleye	5.5	4.5	-	-	-	-	2	13.1	1.9	7.5	3	9.4	4.1	7.4

of that for lake trout (25 ppm).

In view of the large number of variable factors governing the extent of DDT uptake by different fish species, and the small numbers of specimens collected from the Muskoka Lakes to date, no attempt has been made to elucidate the relative significance of these factors in producing the current distribution of DDT levels. Any attempt at doing this would require large samples of many species, age assessments, stomach analyses, and chemical determinations involving considerable expenditure of time and funds. For present purposes it is considered sufficient to establish 'cause and effect' without investigating the precise mechanisms operating in between.

With reference to Table 1, a comparison of mean DDT levels in fish from the three lakes would suggest a higher degree of contamination in Lakes Muskoka and Rosseau in contrast to Lake Joseph. In addition, there is some indication that Lake Muskoka fish show a tendency for higher DDT levels than fish from Lake Rosseau. For example, the mean level for lake trout in Lake Muskoka is 35.1 ppm, while similar values for Lakes Rosseau and Joseph are 23.2 ppm and 17.0 ppm respectively. However, it must be recognized that this comparison does not take into account size differences in the fish comprising the three samples. With this in mind, an attempt has been made to relate DDT concentration in lake trout muscle to weight of fish for each of the lakes (Figure 3 and Appendix C). The method used in making these correlations is known as the principal axis method (Sokal and Rohlf 1969) which overcomes the difficulty of relating two random variables and provides a single axis to represent the trend expressed by the scattergram. By selecting fish of a weight which meets the trend lines in proximity to the points of intersection of principal and minor axes, it is possible to obtain the most valid comparison of DDT levels between the three lakes. Thus, the large majority of three-kilogram fish from Lake Muskoka will have approximately 24 ppm DDT in the muscle, while fish of the same weight from Lakes Rosseau and Joseph will have 23 ppm and 16 ppm respectively. It appears that the true difference between Lake Muskoka and Lake Rosseau lake trout is not as great as the arithmetic mean would indicate, but that Lake Joseph lake trout are significantly less contaminated with DDT than the former.

A principal axis correlation of DDT in lake trout and smelts from nine lakes in the Muskoka area is shown in Figure 4 (OWRC and Department of Lands and Forests data, 1966-1971). Data utilized in the graph are tabulated in Appendix D. Despite the lack of uniformity of sample size and large weight differences in the fish analysed, a good relationship was found between the DDT contents of the two species. This finding suggests that smelts, a major food item in the lake trout diet, may be an important vector in the transfer of DDT to the latter species.

FIGURE: 3 PRINCIPAL AXES FOR THE CORRELATIONS OF MUSCLE BORNE DDE WITH WEIGHT OF LAKE TROUT. MUSKOKA LAKES 1966 TO 1970

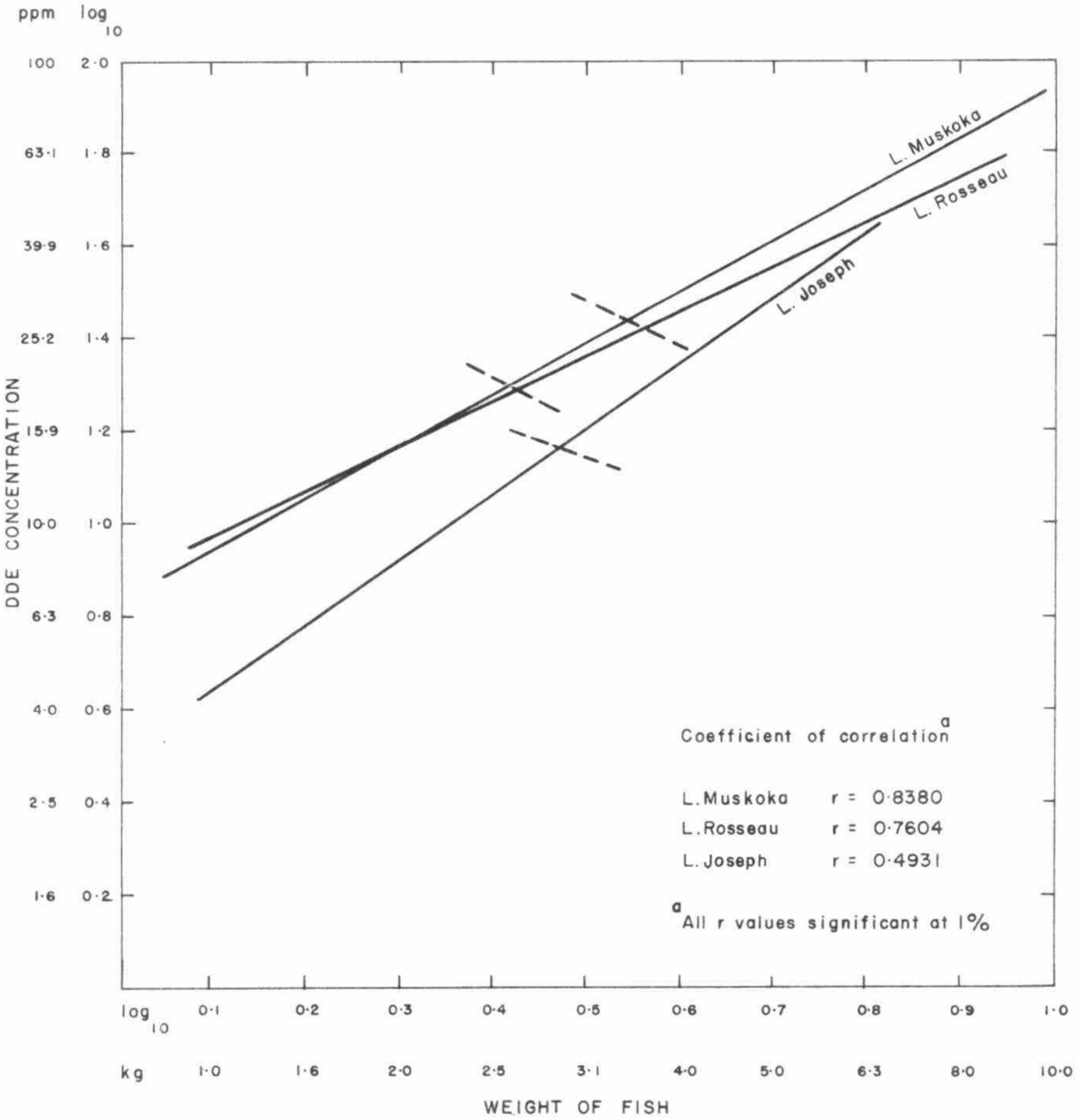
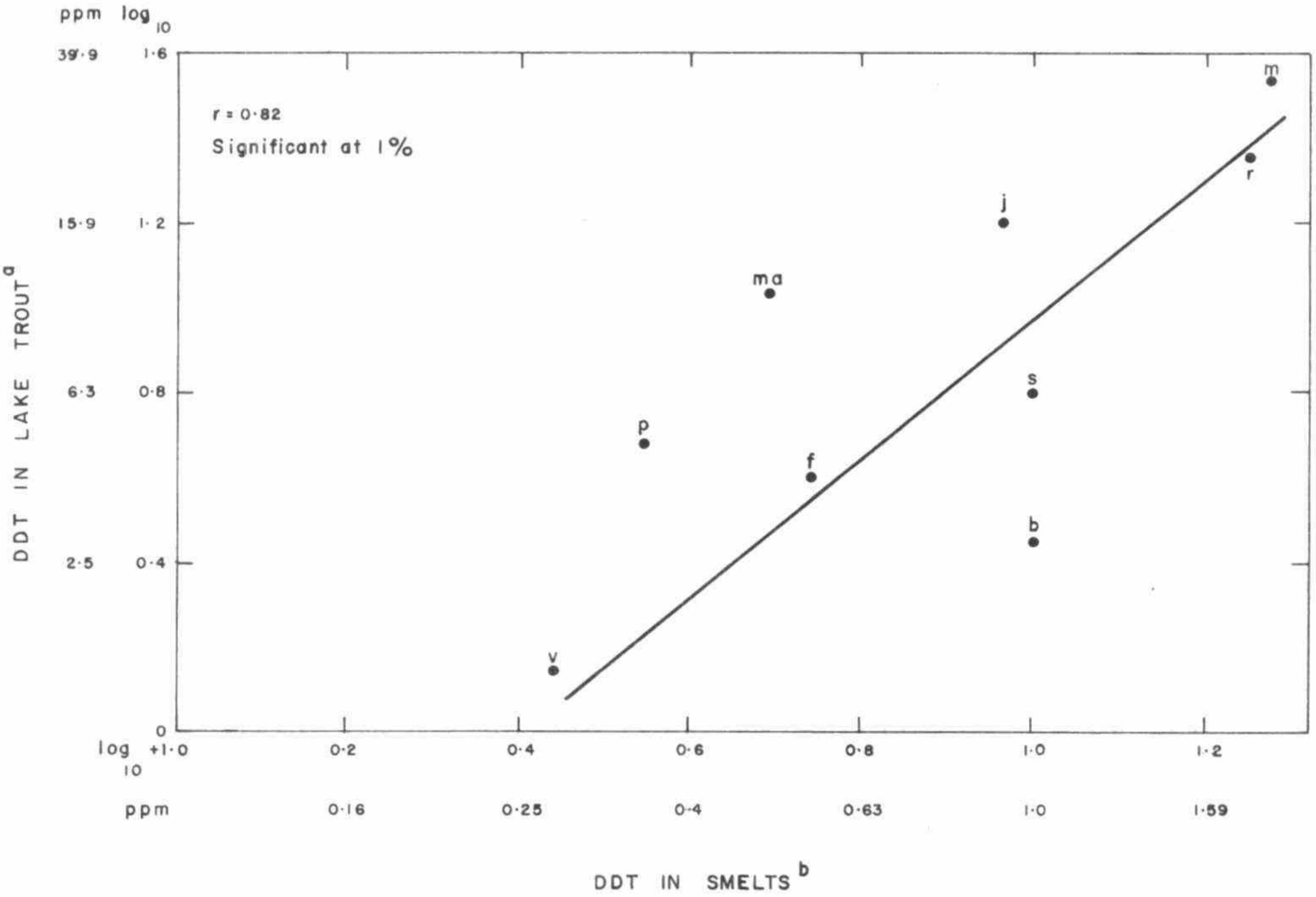


FIGURE: 4 PRINCIPAL AXIS FOR THE CORRELATION OF MUSCLE-BORNE DDT IN LAKE TROUT WITH SMELTS. MUSKOKA LAKES, 1966 — 1971



[a] Lake Trout as DDE [b] Smelts as Total DDT.

f: Fairy Lake, j: Lake Joseph, m: Lake Muskoka, b: Lake of Bays, r: Lake Rosseau,

s: Lake Simcoe, ma: Mary Lake, p: Penninsula Lake, v: Vernon Lake.

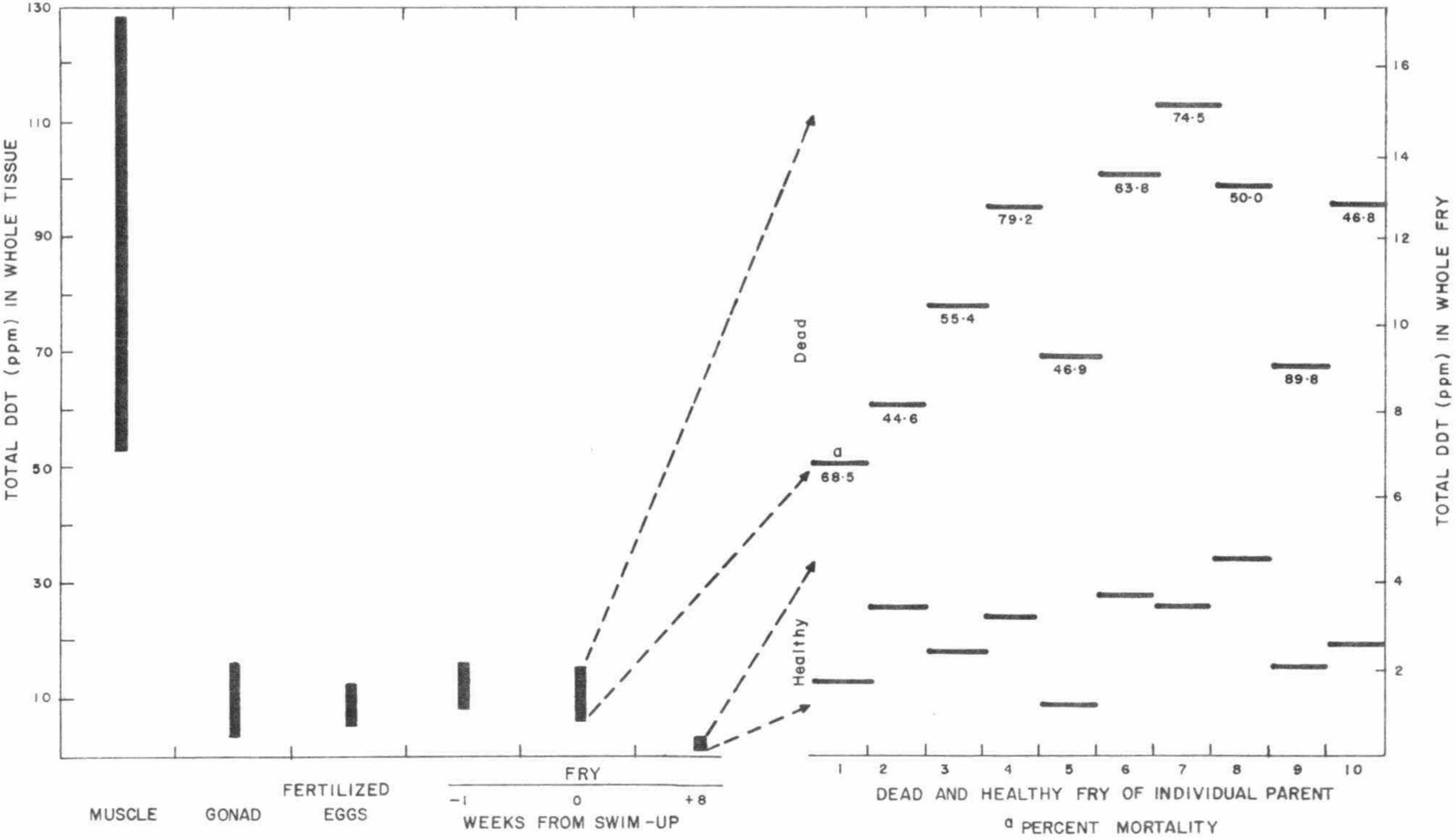
Annual catches of lake trout and other species were not sufficient to precisely define temporal changes in DDT contamination. However, examination of lake trout data obtained yearly from 1966 to 1970 showed no obvious improvements over this period of time. The summary of data in Figure 3 includes all specimens of lake trout taken from the Muskoka Lakes between 1966 and 1970 for which weights were recorded.

In order to ensure the comparability of data produced by various analytical techniques, a number of transformations were required. An outline of the methods employed will be found in the previous section entitled 'Technical Considerations.'

Lake Trout Fry Survival Study

It must be emphasized at the outset that this study was not designed to simulate the work of Burdick referred to earlier. In contrast to the latter study which compared fry mortality in lake trout from a large number of lakes, fish were obtained from one lake only and significant mortality occurred amongst all batches of fry (44.6 - 89.8%). Relationships between ranges of total DDT in muscle, gonad, fertilized eggs and fry of 10 fish from lake Muskoka are portrayed in Figure 5. Total DDT levels are included for fry which died on absorption of the yolk-sac, as well as levels in surviving fry eight weeks later. Complete tabulations of

FIGURE: 5 RANGES OF TOTAL DDT IN MUSCLE, GONAD, EGGS AND FRY OF TEN FEMALE LAKE TROUT FROM LAKE MUSKOKA 1967 AND 1968



data employed in this summary will be found in Appendix E.

Considerable differences exist between DDT concentrations in the muscle (53-128 ppm) and gonad (4.8-15.7 ppm), whereas concentrations in fertilized eggs and fry are not appreciably different to those found in gonad. No relationships could be found between total DDT, its isomers or metabolites and the extent of mortality in individual batches of fry, whether calculated on the basis of fresh tissue or fat content.

In the absence of control data, it is important to ascertain the expected survival of lake trout fry under normal hatchery conditions where interference through DDT contamination is not suspected. Information obtained from discussions with local fisheries personnel indicates that some losses (20-30%) may be expected at the hatching stage, but that subsequent losses of fry are usually minimal (5-10%). This being the case it would appear that total losses of lake trout offspring in excess of 40% are infrequent, and that the high mortality of Muskoka Lake fry in the 1968 study must be considered abnormal. The timing and extent of mortality which occurred are characteristic of the 'syndrome' described by Burdick, and although the existence of other detrimental factors such as poor water quality and disease cannot be completely over-ruled, the indications are strong that DDT levels in the fry were responsible for the losses.

Direct comparison between the Muskoka Lakes survival study and Burdick's work is complicated by differences in analytical techniques and the methods used in expressing results. DDT levels in fry of New York lake trout were computed from analyses of egg lots by applying a calculated factor for weight increase. Furthermore, the levels reported were for combined DDT and DDD but did not include DDE. On this basis, Burdick estimated the threshold level for appearance of the syndrome (mortality greater than 50%) to be 2.9 ppm. Assuming a valid comparison can be made between Muskoka Lake fry and Burdick's 'computed' fry, the levels for total DDT less DDE in the former exceeded 2.9 ppm in all fry lots. It would seem unlikely that differences in recovery of DDT, owing to recent improvements in analytical techniques, would be of sufficient magnitude to affect the conclusion that a high proportion of Muskoka Lake fry contain critical levels of this insecticide.

The similarity between lake trout from Lake Muskoka and Lake Rosseau with respect to DDT levels in muscle and gonad would strongly suggest an equally high incidence of reproductive failure in the latter situation. On the other hand the condition in Lake Joseph, where DDT levels are significantly lower, is more difficult to predict. However, data on 5 female lake trout randomly selected from those available and with weights falling inside the weight range utilized in the survival study, indicated muscle levels of 18-47 ppm and gonad levels of 1.3 - 17 ppm. Since four of the five gonad levels fall within the range of those producing eggs for the survival study (Figure 5), there can be little doubt that some Lake Joseph lake trout are similarly affected.

It would be a great advantage if the quantities of DDT in muscle of adult lake trout could be used to predict the degree of fry survival. The narrow range of DDT levels in gonad, eggs and fry of fish with a wide range of muscle levels, implies that a considerable decrease in adult muscle residues must occur before a significant decrease will be found in the fry. Examination of all data available on female lake trout reveals that gonad levels will not be consistently below 4.8 ppm (lowest level in the 10 survival study fish) until levels in the muscle are approximately 20 ppm or less. It has been estimated that Muskoka Lakes lake trout reach maturity at 6-8 years, and the small quantity of age: weight information which could be found give their weight at this age as 3.6 - 4.5 kg. Taking the lowest weight at 7 years of 3.5 kg., by reference to Figure 3 it will be seen that the majority of 3.5 kg fish from Lakes Muskoka, Rosseau and Joseph have muscle levels of about 27 ppm, 26 ppm and 19 ppm respectively. If this line of reasoning is correct, muscle levels in lake trout from Lakes Muskoka and Rosseau must decrease by at least 25% before improvement in reproductive success can be expected. Furthermore, the marginal status of Lake Joseph with respect to successful reproduction is confirmed to some extent. Observations of future trends will help to verify the applicability of this reasoning.

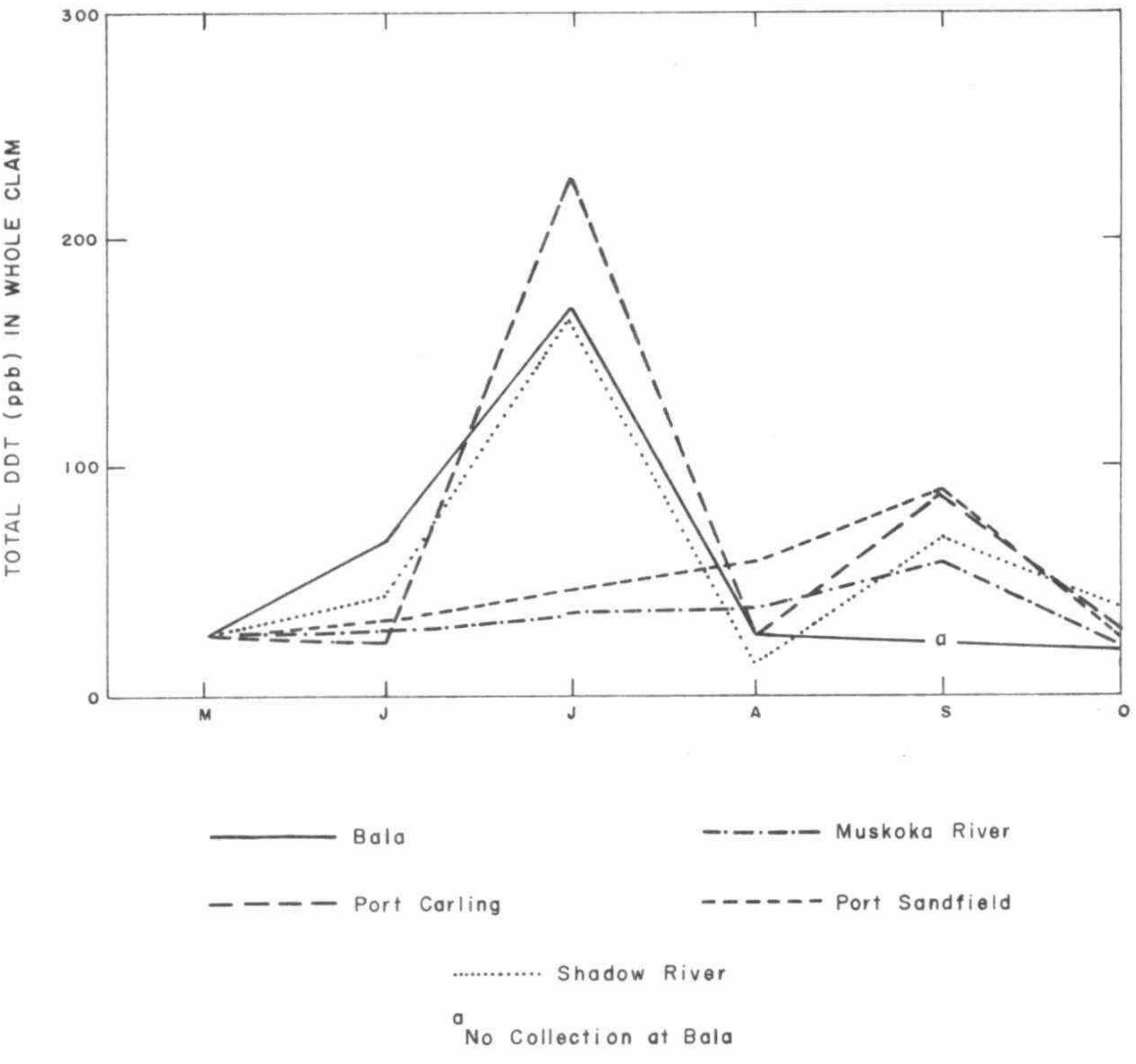
Water, sediments and clams

Results of total DDT analyses performed on water, sediment and clam samples taken from the Muskoka Lakes will be found in Appendix F.

Figure 6 shows mean monthly DDT levels in clams caged at five locations during the summer of 1970. The level for the month of May reflects DDT in the 'stock' population at Sandy Bay, before relocation of the clams. A detailed analysis of the Sandy Bay clam community (Fall 1971), showed a high degree of variation in DDT levels even when samples of five clams were taken and composited (Coefficient of variation = 46%). This implies that in order to show a significant difference with time or location, the concentration of DDT in two samples must differ by almost 100%. On this basis the levels at Bala, Port Carling and the Shadow River in the month of July, 1970 are significantly different to the corresponding levels for June, and are appreciably greater than the July figures for clams at Port Sandfield and the Muskoka River.

Concentrations of DDT at the end of August were similar at all locations and not significantly different to the May condition, whereas small increases were evident in all clams monitored in September. Despite the fact that only two groups of clams showed the required 100% change over the preceeding month (Port Carling and Shadow River), the minor peaks in September are considered

FIGURE : 6 MEAN DDT LEVELS IN CLAMS, MUSKOKA LAKES MONITORING PROGRAM, MAY TO OCTOBER 1970



significant since, in this case, elevations occurred at all stations. It is unlikely that such uniformity would occur by chance alone. In addition, clams collected from Sandy Bay at the same time of year yielded a mean level within the range established for the other stations.

No particular importance can be attached to the clam results for 1970 other than to emphasize the fact that levels of DDT in a more or less sendentary organism may vary with season and geographical position within the system. In general, the quantities of DDT present in Muskoka Lakes clams are within the ranges established elsewhere in the Province, but levels at Port Carling, Bala and the Shadow River in July 1970, were substantially elevated, even exceeding concentrations found in clams located in watersheds where DDT uses continue. Clams taken from Cook Bay in Lake Simcoe, which receives drainage from the Bradford Marsh, showed DDT levels of 80 - 120 ppb (OWRC data July 1969). The use of this insecticide in the marsh area continued until recently under special licence, since it provided the only satisfactory means of controlling cutworms which may cause serious damage to onion and carrot crops. High residues of DDT in sediments and fish from the Holland-Schomberg river system which drains the marsh, suggest that over the years DDT has been transported into Lake Simcoe. The high levels in clams from Cook Bay likely reflect small but steady water-borne inputs of this chemical to the lake, since the sandy sediments which clams inhabit contain low concentrations of DDT (5-7 ppb); yet the possibility exists that some portion of these residues orginated from mosquito control activities around the lake shore and not from the Holland Marsh. In view of the knowledge that DDT persists for long periods in forest soils (Yule, 1970), it would be reasonable to attribute the high Muskoka Lakes values to similar active inputs from the watershed of that area.

It has already been noted in the discussion of fish contamination, that accumulation of DDT by particular aquatic fauna is dependent on many factors in addition to the quantity and distribution of the pesticide within the environment. Thus, the amount of DDT present in clams at any one time will be the product of two groups of factors both of which are governed by the influences of climate and season. The first group includes all factors governing the extent and rate of food intake such as the nature and abundance of food organisms. The second group of factors comprises the various levels of DDT to be found in water, sediment and in the biological material on which the clam feeds. Each factor involved will seldom adopt a steady state but will vary in magnitude with seasonal and climatic conditions and with the dynamics of associated factors. For example, the availability of food will tend to increase with rising water temperature between spring and mid-summer, while DDT inputs to the system may be dependent on contributions from spring melt-water and occasional high rainfall. Thus, there will be a general tendency for DDT uptake to increase from April to July, although deviations from the trend might be expected at some locations depending on the extent of exposure to terrestrial inputs carried into the lake with run-off. Regional differences in clam DDT levels will also be apparent where sediment conditions are dissimilar, since clams, which continuously circulate particles of the substrate through their filtering mechanism, will eventually achieve some sort of an equilibrium with the sediment concentration. Lastly, full recognition must be given to the inherent variability between individual clams which, as evinced by those from Sandy Bay may be surprisingly high even when outside influences are constant.

The foregoing discussion points out some of the problems involved in interpreting data concerning pesticide contamination in aquatic biota. For example, the high levels of DDT found in clams at three stations in the Muskoka Lakes during July of 1970 could be related to greater food availability at these locations rather than to any significant differences in the extent of DDT contamination. In an attempt to clarify some of the more important factors involved additional work was undertaken in the fall of 1971 when comparisons were made between water, sediment and clam concentrations at seven locations including some of those monitored in 1970.

Table 2 shows the results of water, sediment and clam analyses performed on samples collected in September 1971. With the exception of one sample taken from an 80' depth in Milford Bay, which may have become contaminated with minute quantities of sediment, all water samples contained extremely low levels of DDT typical of those found

TABLE 2:

TOTAL DDT IN WATER, SEDIMENT AND CLAM COMPOSITES,
EXPRESSED AS ppb
MUSKOKA LAKES, SEPTEMBER, 1971.

	DDT Concentration		
Station	Water	Sediment[a]	Clams (Caged)
Muskoka River	0.009	1.9	24
Bala	0.010	8.6	-
Shadow River	0.009	1.1	35
Port Carling	0.011	23.1	53
Port Sandfield	0.008	6.4	32
Milford Deep	0.042	15.1	56
Milford Shallow	-	56.4	54
Port Cockburn	0.019	3.2	26

[a] Dry Weight.

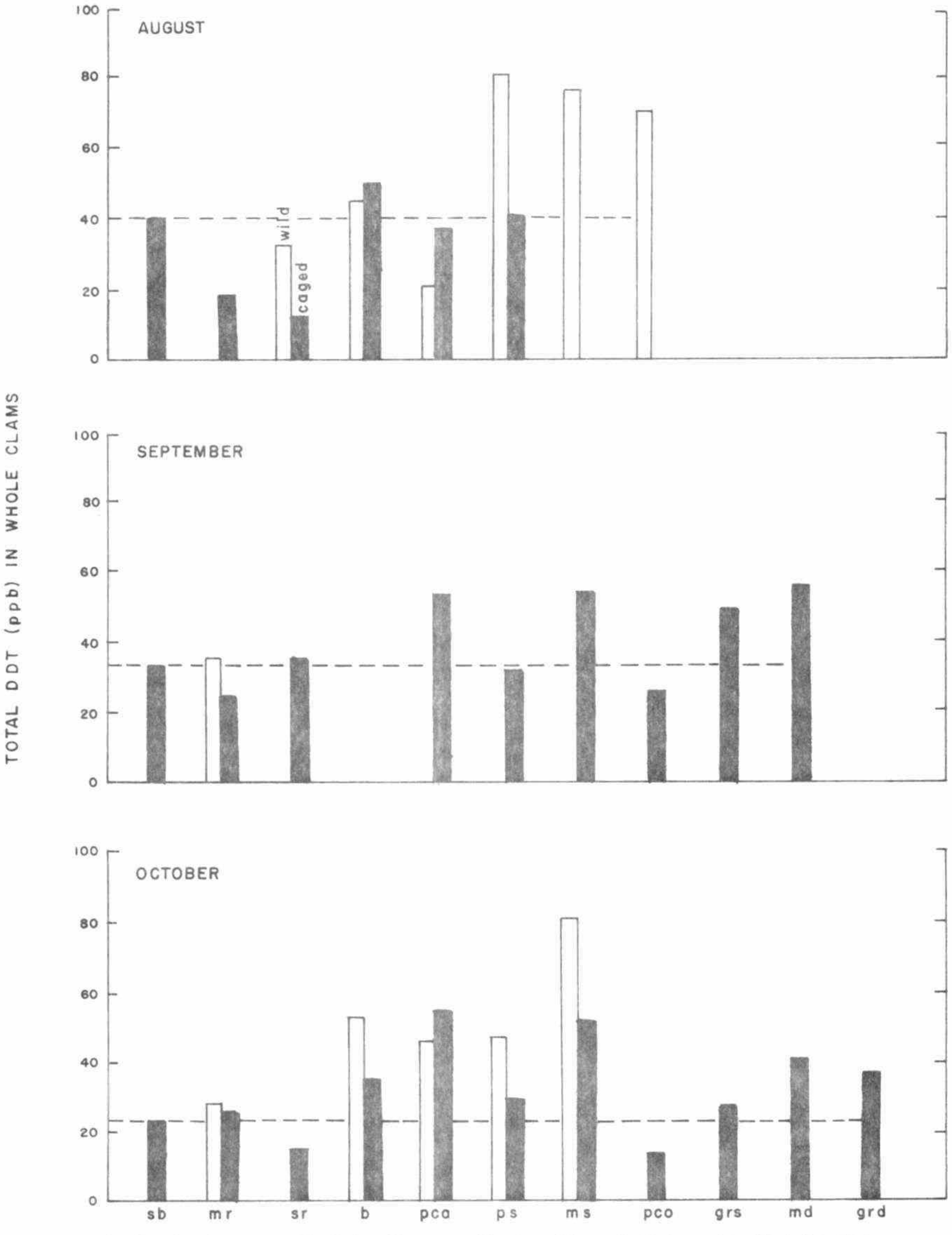
in many surface waters of the United States (Edwards 1970), and in the St. Lawrence River, (Wong 1968). Water samples were not filtered and therefore reflected DDT as adsorbed onto any organic material present as well as that contained in solution. Since no significant differences were apparent between individual water samples no relationships were evident between water and sediment or water and clams.

Sediment levels varied to a greater degree than water with highest values obtained at Port Carling, Milford Shallow and Milford Deep. It is interesting to note that clam DDT levels at these three stations were somewhat higher than those found at other localities, suggesting that clams are influenced to some extent by the substrate which they inhabit. The sediment concentrations of DDT reflect the past histories of contamination at each locality and therefore provide a useful index of regional differences with respect to DDT usage patterns. Clams however, may serve a more useful purpose since they not only reflect the historical situation but may in addition show the presence of elevated water levels if and when they occur.

The importance of monitoring DDT in water in areas where historical use appears to have been high should be emphasized, since the continuing presence of elevated water-borne residues will imply that terrestrial deposits of the chemical are still entering the lake and will serve to prolong the time required for rehabilitation of the sport fishery. The limitations of spot water samples in this connection have been discussed earlier, and since clams are capable of reflecting recent changes in DDT levels it would seem appropriate to continue to utilize this organism for monitoring water-borne residues. However, in order to use the clam for this purpose it would be necessary to differentiate between the influences of sediment and water, and it is suggested that they be placed at the monitoring site in suitable containers with sediment transported from a control area having generally low DDT levels. In this way a comparison between the control and monitoring sites would give a more valid measure of water-borne DDT, since interference from sediment residues would be equal in both situations.

Figure 7 shows DDT levels in wild and caged clams sampled from August to October 1971 inclusive. With the exception of Sandy Bay, where much larger samples were collected, most values are means of two, five-clam composites and each month all stations are compared to the population at Sandy Bay. The caged clams picked up in August had been placed in the fall of 1970, and thus had ample time to adjust to their new environment. In this month substantial differences were found between wild and caged clams at the Shadow River and Port Sandfield, where accessibility prevented the placement of the cages on the sediment, and they were instead lodged in rocky crevices. These differences support the contention that sediment residues play a significant role in determining the magnitude of DDT levels within the clam. By contrast, discrepancies

FIGURE: 7 MEAN DDT LEVELS IN WILD AND CAGED CLAMS. MUSKOKA LAKES MONITORING PROGRAM, AUGUST TO OCTOBER 1971



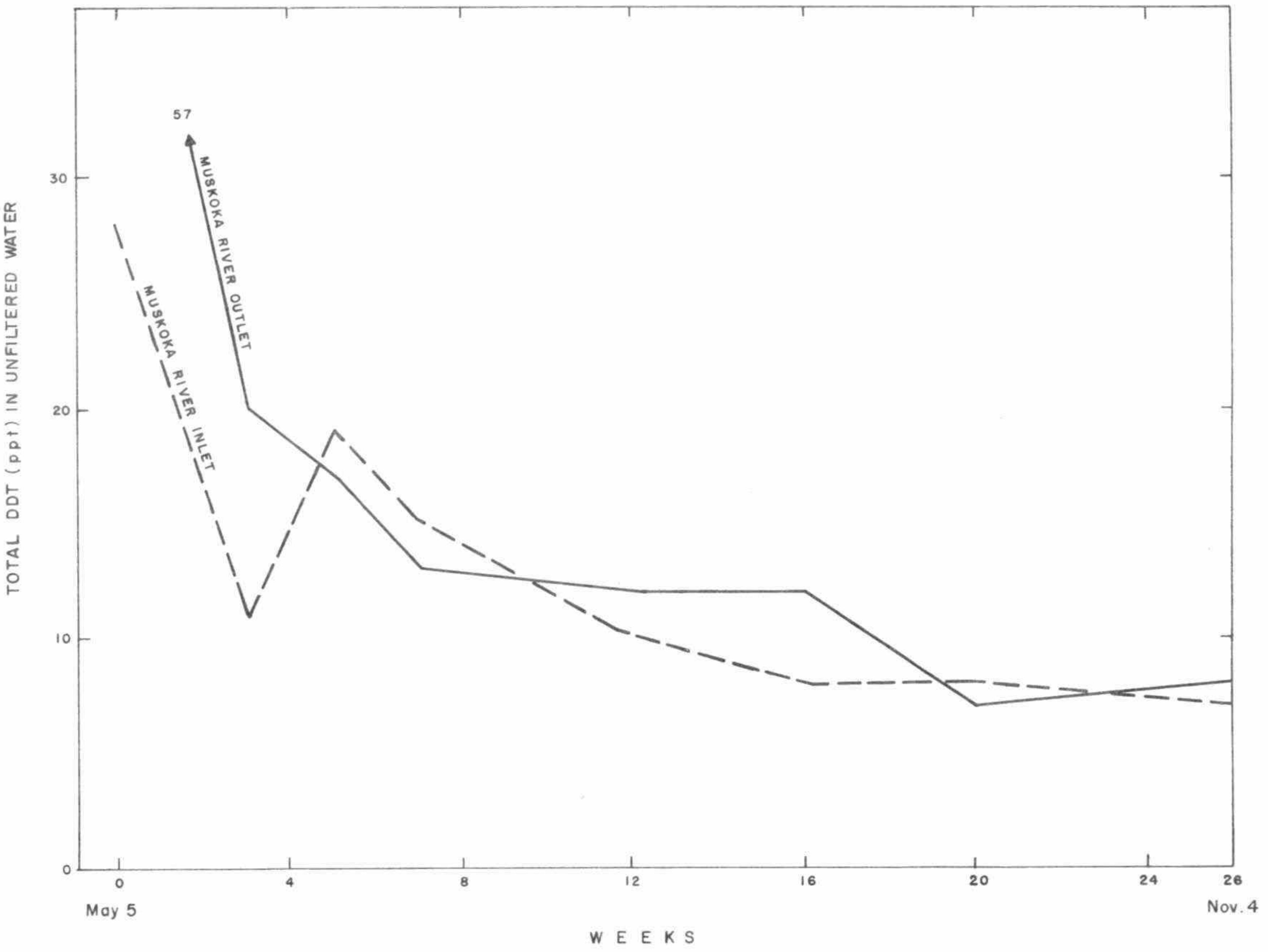
sb: Sandy Bay, mr: Muskoka River, sr: Shadow River, b: Bala, pca: Port Carling, ps: Port Sandfield, ms: Milford Shallow, pco: Port Cockburn, grs: Gravenhurst Shallow, md: Milford Deep, grd: Gravenhurst Deep.

between wild and caged clams at Bala and Port Carling which were all placed on sediment, are most likely related to inherent sample variability rather than to differences in habitat. The August collections indicated greater contamination at Port Sandfield, Milford Shallow and Port Cockburn as compared to Sandy Bay, whereas levels in clams at two major stream inputs, the Muskoka and Shadow rivers, were suggestive of low residues entering the lakes at this time. DDT levels in clams at these two river stations remained low throughout the fall period, verifying the results of water sampling which indicated a progressive decline in DDT inputs from the Muskoka River over the summer season (Figure 8).

Cages picked up in September and October contained clams relocated from Sandy Bay in the latter part of August. Over the two-month period, mean levels at Sandy Bay decreased from 40 to 24 ppb while relocated clams showed gradual adjustments to their new environments with a concomitant tendency to attain DDT levels similar to the wild populations. By the end of October, the combined figures for both wild and caged clams at Milford Bay suggested that this site may be contaminated to a greater degree than other areas studied, while Port Carling, Port Sandfield and Bala, which like Milford Bay have relatively high human population densities, appeared intermediate in contamination.

Sections of the Milford Bay shoreline are known to have received heavy applications of DDT for biting fly control up until the mid-sixties, and these activities are reflected in both the deep and shallow sediments of Milford Bay (15.1 and 56.4 ppb respectively).

FIGURE : 8 DDT IN MUSKOKA RIVER INLET AND OUTLET MAY TO NOVEMBER 1971



While the concentration of DDT found in sediment from deep water is significantly less than that from shallow water, it is likely that greater quantities of pesticide are deposited per unit area in the deeper sections of the bay. The light texture of profundal sediments will permit the sampling dredge to penetrate deep into the ooze and samples obtained will not represent the upper stratum where the highest levels of DDT are to be expected. Deep water residues may therefore be substantially diluted by mixing with underlying sediment deposits. Furthermore, the strong affinity of DDT for organic particles would suggest that the highly organic profundal ooze would contain more DDT per unit weight than the mineral sediments of the shallow water. These points suggest that a considerable quantity of DDT may be deposited in the deeper lake basins. If this theory is correct, it would seem that DDT applied in past years to shoreline areas could have been moved progressively from the land into the shallow in-shore waters, and subsequently carried by waves, currents and decaying biota to an ultimate reservoir in the deeper portions of the lake. Thus it may be, that the Milford Bay area and a number of other populated localities around the Muskoka Lakes have been acting as feeders of DDT to the deep, cold, lake habitat where lake trout and whitefish presently carry high body burdens of this insecticide.

For the past six years, no DDT is known to have been used in the Muskoka Lakes district for forest protection or biting fly control purposes. Although sufficient time has now elapsed for the major portion of terrestrial DDT to be transported into the lakes, no evidence exists to suggest that this process has ceased entirely.

DDT decays slowly even under warm aerobic conditions, but degradation in the deep, colder water and in sediments which are frequently anaerobic, proceeds at a still slower rate. Since degradation to innocuous products, both in the biota and their environment, hold most promise in bringing about gradual improvements in the status of DDT contamination in the lakes, it may be somewhat premature to expect improvements if the material currently undergoing degradation is continuously being replaced by low, but steady contributions from the land. The situation at Milford Bay provides an ideal opportunity for investigating future trends in this connection. Continued application of the clam monitoring techniques at this locality during peak feeding periods in mid-summer, may provide the most economical and efficient method of detecting water-borne residues of DDT at a major point of entry to the system. Furthermore, clams should provide a record of continuing input trends as compared to any trends in fish. If, for example, residues in fish decrease over a period of time while clam residues continue to indicate terrestrial inputs at Milford Bay, it will be evident that total shoreline inputs are not significant at this time other than to the degree that they are prolonging the recovery period of the system. Clams may thus provide a valuable method for obtaining information which may be applied to other, similarly contaminated areas.

Figure 8 shows DDT concentrations in water entering the system through the Muskoka River, and leaving through the outlet at Bala, between May and November, 1971. High levels were detected in early May at both stations (28 and 57 ppt respectively), which support the contention that spring melt-water is responsible for the major portion of the gross annual DDT input to the system. It is of interest to note that studies undertaken by the Canada Department of Agriculture, London, Ontario (Miles and Harris, 1971) have shown that DDT concentrations in river water draining agricultural land where DDT remains in use, were similar to concentrations found in the Muskoka River between April and October.

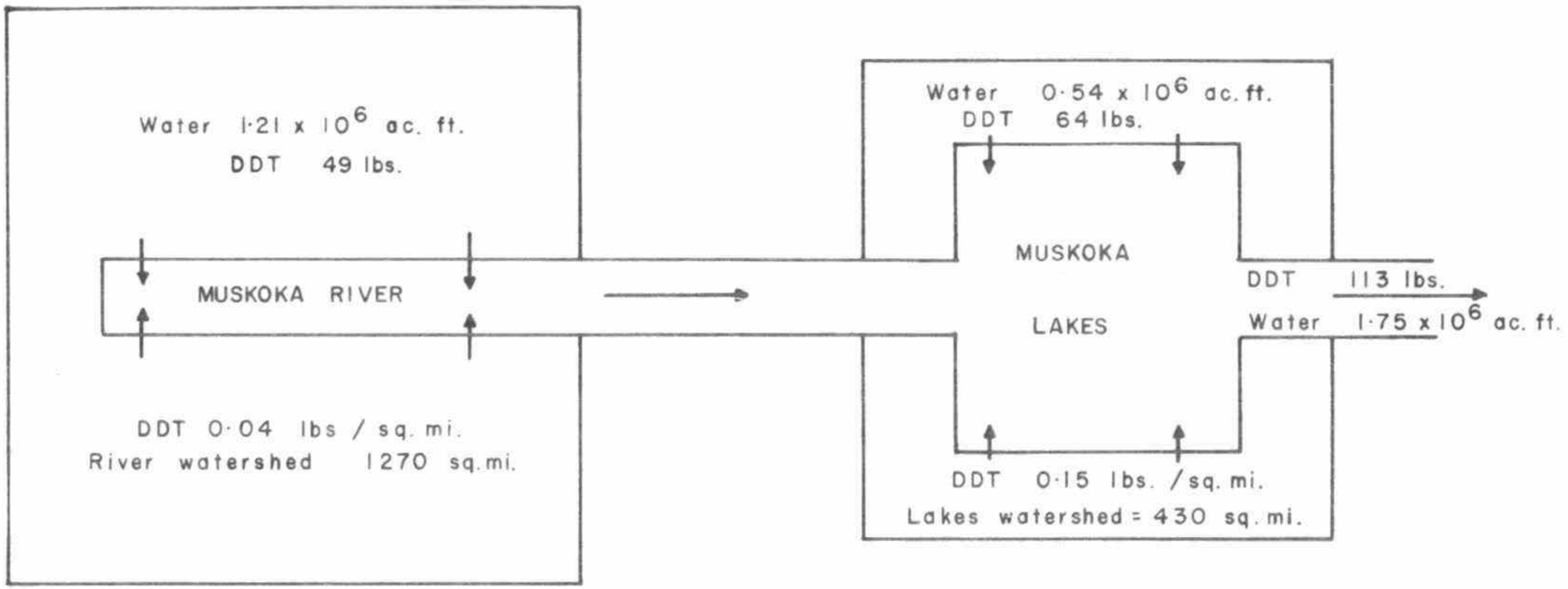
The high level recorded at the outlet suggests that this increased water load has a salutary effect in flushing DDT from the lakes, but the discrepancy between input and outflow concentrations more likely reflects the additional load from sources other than the Muskoka River. Undoubtedly, smaller streams and shore-line inputs account for a significant fraction of the total load and must be considered in any discussion of a DDT budget for the system. However, the data available are quite inadequate to calculate an accurate budget and present considerations relate solely to an estimate of Muskoka River inputs compared to other sources. Furthermore, no attention is paid to possible contributions from precipitation, yet studies clearly show that atmospheric 'fallout' of chemical residues may be a continuing source of DDT contamination in certain regions (Cohen & Pinkerton 1966).

No data are available on DDT levels in the Muskoka River between the months of November and April so rough approximations have been made to facilitate calculation of an estimated annual input and discharge at the upstream and downstream stations respectively. The method used involved the assumption that concentrations at both inlet and outlet in April were identical to those in May; February and March were equivalent to June; and October, November, December and January were each assumed to have residues of 10 ppt at both stations. Flow data were obtained from Environment Canada (Water Survey) at Guelph.

Calculations based on the foregoing data indicate that in 1971 the total DDT loading to the system through the Muskoka River was 49 lbs, of which approximately 68% was delivered over the months of March, April and May, while equivalent figures for DDT leaving the system were 113 lbs and 78%.

The volume of water entering the system from all sources other than the Muskoka River has been obtained by difference from the total 1971 discharges at the inlet and outlet of the Muskoka River. Such sources appear to account for 31% of the total input. If it were assumed that the mean annual concentration of DDT was the same in both portions of the total water input, then about 22 lbs of DDT would be contributed to the system yearly from the smaller rivers and shoreline run-off. This does not appear to be the case however, since a total of 113 lbs of DDT is being discharged from the lakes. This would indicate the total contribution from shoreline run-off and smaller streams would be approximately 64 lbs, and the average concentration of DDT would be 2.9 times that of the Muskoka River inputs (Figure 9). It would seem reasonable to speculate that the loading may even exceed that stated above since, according to Edwards, DDT becomes rapidly adsorbed onto particulate matter on entering a water body and may become incorporated into the sediments.

FIGURE : 9 SIMPLIFIED ESTIMATE OF DDT BUDGET. MUSKOKA LAKES 1971


Water 1·21 x 10^6 ac. ft.
DDT 49 lbs.
MUSKOKA RIVER
DDT 0·04 lbs / sq. mi.
River watershed 1270 sq. mi.
Water 0·54 x 10^6 ac. ft.
DDT 64 lbs.
MUSKOKA
LAKES
DDT 113 lbs.
Water 1·75 x 10^6 ac. ft.
DDT 0·15 lbs. / sq. mi.
Lakes watershed = 430 sq. mi.

WATER

Muskoka River Watershed input = 1·21 x 10^6 ac. ft. (A)
Muskoka River total output = 1·75 x 10^6 ac. ft. (B)
Muskoka Lakes Watershed input (B – A) = 0·54 x 10^6 ac. ft. (C)
Factorial Difference $\frac{C}{A}$ = 0·45

DDT

DDT load Muskoka River input = 49 lbs. (D)
DDT loss Muskoka River output = 113 lbs. (E)
Estimated DDT load Muskoka Lakes watershed E – D = 113 – 49 = 64 lbs. (F)
Factorial difference $\frac{F}{D}$ = 1·3

Estimated average DDT Concentration from Muskoka Lakes watershed in Muskoka River input = $\frac{1 \cdot 3}{0 \cdot 45}$ = 2·9 times concentration

It might be argued that the elevated DDT levels at the outlet could result from a flushing action wherein particles of contaminated bottom sediment are transported into the water phase by mixing which occurs prior to thermal stratification. This may be partially the case, but comparisons of the composition of DDT in sediment and water (Table 4) clearly show that outlet water does not reflect the residues found in sediments.

It is fully recognized that in making the calculations relevant to Figure 9 the Muskoka Lakes are considered as a single entity with complete interchange of water, and that it would be unrealistic to expect shoreline inputs into Lakes Rosseau and Joseph to exert as much influence on the concentrations of DDT at the outlet as contributions from the more immediate shoreline of Lake Muskoka. If it were assumed that the differences in input and output loading are a function of shoreline runoff from Lake Muskoka alone, then such contributions are even more significant than the computations would suggest, since in this case, the drainage areas surrounding Lakes Rosseau and Joseph would not be included.

In view of the contaminated conditions at some shoreline areas and the knowledge that DDT was applied heavily to the periphery of the Muskoka Lakes these observations are not surprising. Undoubtedly the most significant point which emerges from the computations is that the transport of terrestrial DDT residues from the drainage area directly adjacent to the lakes appears to be more important than that from the larger, more distant, Muskoka River watershed. Respective estimates of the contributions from each area are 0.15 and 0.02 lbs/sq mile/year.

Presumably the present day inputs of DDT to the system are small compared to those which occurred at the time DDT was being applied and serve only to prolong the time required for purging of the system. The evidence suggests, however, that the recovery period will be of considerable duration.

Magnification factors

Table 3 summarizes all data used in this report obtained from water, sediment, clam and fish analyses. Using median values as indices for each sample type, magnification factors have been calculated relating residues in sediment, clams and warm-water and cold-water fish to those found in water. While sediments show lower concentrations than clams and fish, the total weight of contaminated sediment will far exceed the standing crop of indigenous biota and unquestionably incorporates the greater portion of all the DDT within the Muskoka Lake system. The magnification factors presented do not in themselves demonstrate food-chain transfer, since the clam is not a part of the trophic system by which food energy is relayed to fish. Nonetheless, the concentration of DDT is usually much higher in the biota than in the water and it is concluded that the food chain is the major source of DDT for fish in natural waters.

Distribution of DDT isomers and metabolites

Table 4 shows the percentages of DDT isomers and metabolites found in water, sediments, clams and fish. Mean percentages of the parent compound (p,p'DDT and o,p'DDT) were 84%, 27%, 25% and 49% respectively. The high proportion of these isomers in water suggests that much of this DDT is of recent origin. Residues occurring in fish contain a large proportion of the metabolite p,p'DDE, which may have

Table 3: TOTAL DDT IN MUSKOKA LAKES WATER SEDIMENT CLAMS AND FISH, EXPRESSED IN TERMS OF WET WEIGHT, 1966-1971.

	Number Samples	DDT Units	Range Max.	Range Min.	Median	Magnification Factor* (approx)
Water	4	ppb	0.04	0.001	0.02	
Sediment	6	ppb	33.8	2.0	17.9	0.9×10^3
Clams	17	ppb	229.0	21.0	125.0	6.3×10^3
Warm-water fish	141	ppm	15.4	0.05	7.8	390×10^3
Cold-water fish	302	ppm	142.0	0.21	71.1	$3,555 \times 10^3$

* Related to water

Table 4: MEAN PERCENT DDT ISOMERS AND METABOLITES IN WATER,
SEDIMENT, CLAMS AND FISH IN THE MUSKOKA LAKES
1966 - 1971.

	No. Samples	p,p'DDE	p,p'DDD	o,p'DDT	p,p'DDT
Water	19	11	5	17	67
Sediment	8	29	41	4	23
Clams	25	27	49	7	18
Cold-water fish					
Lake trout	10	33	10	8	49
Whitefish	10	32	13	8	47
Warm-water fish					
White sucker	10	45	18	3	38
Rock bass	10	41	15	3	41

been formed in the fish, or more probably, earlier in the food chain (Holden, 1966). The high percentages of the metabolite p,p'DDD observed in sediments are likely a result of degradation under anaerobic conditions (Guenzi and Beard 1967), while the large amount of this product in clams is, at least in part, a reflection of the substrate.

While no substantial differences are apparent between cold and warm-water fish species, it is of interest to note that the proportion of p,p'DDT in the latter is slightly less than the former. This discrepancy likely reflects the more rapid breakdown of p,p'DDT under warmer water conditions, suggesting that warm-water fish species might provide the earliest indication of general improvement in the status of fish contamination.

Burdick concludes that p,p'DDT and p,p'DDD contribute the major hazard with respect to DDT-induced reproductive failure in lake trout. If this is the case, some improvement from existing conditions should be apparent with an increase in the proportion of p,p'DDE relative to the combined amounts of p,p'DDT and p,p'DDD. Future analyses of Muskoka Lakes fish will indicate whether a shift in this direction is likely to occur, and if so, greater importance might be attached to this ratio than to any tendency for a reduction in the total DDT complex.

The consumption of DDT contaminated fish

It is well recognized that residues of the insecticide DDT are to be found in a large variety of human foodstuffs, since this chemical is now a contaminant of crop-producing soils and water in many parts of the continent. Despite recent restrictions on the use of DDT for all but high priority purposes no immediate elimination of residues is to be expected, and the human population will undoubtedly be exposed to trace quantities of DDT for many years to come. (Anon. Nature, 1971).

In Canada, residue tolerances for a wide variety of pesticides in many food commodities produced by the nation's farmers are established under the Food and Drugs Act of Canada and administered by the Department of National Health and Welfare in Ottawa. A residue tolerance provides a measure of the amount of a particular pesticide legally permitted in a food product offered for sale to the consumer. Foods containing residues below the tolerance level are considered safe for a lifetime of normal consumption. In order to protect the entire population, consumption estimates utilized in setting tolerances are set at a high level.

The residue tolerance for DDT in fish taken by commercial fishermen in the Great Lakes, and agreed to by both the Canadian and United States governments, is 5 parts per million in the edible tissue. At the present time, no tolerance for DDT has been established or enforced for Ontario inland waters, since little commercial fishing is carried out in significantly contaminated areas.

The residue tolerance system provides no protection to citizens who procure food by their own efforts. Whereas the home gardener may provide his own safe-guards against excessive residues by following pesticide directions meticulously, the sports fisherman cannot be responsible for the past actions of other individuals and must depend on local and provincial health authorities to publicize warnings whenever these are deemed necessary. No such warnings have been provided to resident or visiting anglers in the Muskoka Lakes district despite the fact that lake trout in Lakes Muskoka, Rosseau and Joseph may contain DDT at ten times the Great Lakes residue tolerance.

It must be concluded that, in the opinion of the provincial health authority, no potential hazards exist with eating lake trout from the Muskoka Lakes, although no statement has yet appeared to this effect. Since the average DDT level is unquestionably higher than that considered safe for a lifetime of normal consumption, health authorities presumably feel that consumption rates for lake trout, whitefish and cisco from the Muskoka Lakes are well below normal. While this assumption may be perfectly correct, it should be validated by a suitable census so that all citizens and visitors, including those with special desires and special needs, are afforded the same degree of protection. In addition, the findings and conclusions drawn from the census should be well publicized and available for public examination at all times.

REFERENCES

ADVISORY COMMITTEE ON POLLUTION CONTROL. Interim Report on the Control of DDT Use in the Province of Ontario, March,1969.

ANONYMOUS. DDT Nailed Again. Nature, 233:299, 1971.

BEDFORD, J.W., E.W. Roelofs and M.J. Zabik, The Freshwater Mussel as a Biological Monitor of Pesticide Concentrations in a Lotic Environment. Limnology and Oceanography, 13:118, 1968.

BURDICK, G.E., E.J. Harris, H.J. Dean, T.M. Walker, Jack Skea and David Colby, The Accumulation of DDT in Lake Trout and the Effect on Reproduction. Transactions of the American Fisheries Society, 93(2):127, 1964.

CHEN, J.M. and Cecil Pinkerton, Widespread Translocation of Pesticides by Air Transport and Rain-out. Advances in Chemistry Series, 60:163,1966.

EDWARDS, C.A., Persistent Pesticides in the Environment. CRC Critical Reviews in Environmental Control, 1(1):7, 1970.

GUENZI, W.D. and W.E. Beard, Anaerobic Biodegradation of DDT to DDD in Soil. Science, 154 (3778): 116, 1967.

HICKEY, J.J. and D.W. Anderson, Chlorinated Hydrocarbons and Egg Shell Changes in Raptorial and Fish-eating Birds. Science N.Y., 162:271, 1968.

HOLDEN, A.V., Organochlorine Insecticide Residues in Salmonid Fish. Journal of Applied Ecology, 3 (suppl.): 45-53p., 1966.

MACEK, K.J. and S. Korn, Significance of the Food Chain in DDT Accumulation by Fish. Journal of the Fisheries Research Board of Canada, 27:1496, 1970.

MILES, J.R.W. and C.R. Harris, Insecticide Residues in a Stream and a Controlled Drainage System, in Agricultural Areas of Southwestern Ontario. Pesticides Monitoring Journal, 5:289, 1971.

ONTARIO PESTICIDES ADVISORY BOARD, A Report on the Use of DDT in the Province of Ontario, September, 1969.

WONG, H.F. and J.P. Donnelly, A Preliminary Pesticide Survey in the Bay of Quinte and International Section of the St. Lawrence River. Division of Public Health Engineering, Department of National Health and Welfare, Manuscript Report No. KR-68-4, 1968.

YULE, W.N., DDT Residues in Forest Soils. Bulletin of Environmental Contamination and Toxicology, 5(2): 139, 1970.

APPENDIX A

PROCESSING AND ANALYTICAL TECHNIQUES CURRENTLY EMPLOYED FOR DDT ANALYSIS

OWRC - Laboratories

Live clams were shucked and whole clam composites extracted azeotropically with benzene. Aliquots of the extracts were subjected to Florisil column cleanup, and analyzed by gas chromatography, using an electron capture detector and an 11% (O.V. 17/Q.R.-1) in Gas-Chrom. Q. Column.

Provincial Pesticide Residue Testing Laboratory

Fish samples were thawed and muscle obtained from a cross-section immediately anterior to the anal vent. Tissue was mixed with anhydrous sodium sulfate and sand and was homogenized with a mortar and pestle.

Samples were Soxhlet extracted with hexane and subjected to Florisil column cleanup. Eluates were concentrated just to dryness and residue was redissolved in hexane and stored.

Analysis was accomplished by gas chromatography using an electron capture detector and a 10% (S.E.-30 + Q.F.-1) on Chromosorb W. Column.

Canada Department of Agriculture, Research Institute Laboratories

Wet sediments were mixed in a tray and representative samples extracted with acetone and hexane. Water samples were extracted with hexane alone and the extract dried with anhydrous sodium sulfate.

The extracts were subjected to Florisil column fractionation and analyzed by gas chromatography. Identities of the insecticides reported were in agreement on three G.L.C. columns; i.e. 5% x E.60 on Aeropak, 5% D.C.-200, and a mixed 5% (D.C.-200/Q.F.-1) on Gas-Chrom. Q.

APPENDIX B

COMMON AND SCIENTIFIC NAMES OF FISH SPECIES REFERRED TO IN THIS REPORT.

Common Name	Scientific Name
American smelt	Osmerus mordax
Brown bullhead	Ictalurus nebulosus
Burbot	Lota lota
Lake trout	Salvelinus namaycush
Lake whitefish	Coregonus clupeaformis
Muskellunge	Esox masquinongy
Pumpkinseed sunfish	Lepomis gibbosus
Rock bass	Ambloplites rupestris
Shallow-water cisco	Coregonus artedii
Smallmouth bass	Micropterus dolemieu
White sucker	Catostomus commersoni
Yellow perch	Perca flavescens
Yellow walleye	Stizostedion vitreum

APPENDIX C

DDT IN LAKE MUSKOKA LAKE TROUT MUSCLE, EXPRESSED AS ppm DDE WET WEIGHT, 1966-1970

Year Collected	Weight (kg.)	DDE	Year Collected	Weight (kg.)	DDE	Year Collected	Weight (kg.)	DDE
1966	9.7	71.5	1969	6.0	32.5	1969	2.9	16.8
	8.3	72.4		3.6	26.1		2.3	10.5
	2.3	14.6		3.1	23.0		0.7	6.3
	7.1	101.0		2.2	17.5		8.7	48.4
1967	8.2	75.0		2.6	23.5		7.7	29.4
	5.8	66.5		2.6	23.9		2.1	20.7
	7.4	58.0		2.5	22.6		6.4	38.7
	8.1	72.5		2.5	18.1		0.8	12.4
	5.9	54.7		8.5	115.0	1970	3.7	42.4
	6.3	14.8		9.2	61.2		0.2	1.9
	7.7	46.0		1.9	7.3		2.4	33.6
	2.6	36.2		2.3	18.8		2.9	56.3
	1.4	25.7		3.0	20.3		2.8	52.9
	9.6	81.9		2.4	16.8		3.1	16.3
	6.0	29.2		2.8	23.6		4.3	41.6
	7.6	58.0		6.3	29.4		3.5	44.1
	10.0	101.9		4.1	19.7		0.9	5.1
1968	7.3	76.3		2.8	24.0		2.0	11.9
1969	1.8	17.2		8.9	68.8		1.7	8.8
	3.1	22.5		1.9	21.8		3.8	42.6
	4.2	30.3		3.0	7.2		3.6	17.9
	3.1	21.4		2.2	15.9		2.7	47.9

APPENDIX C

DDT IN LAKE ROSSEAU LAKE TROUT MUSCLE EXPRESSED AS ppm DDE, WET WEIGHT, 1966-1970

Year Collected	Weight (kg.)	DDE	Year Collected	Weight (kg.)	DDE	Year Collected	Weight (kg.)	DDE
1966	9.0	29.3	1967	1.1	12.6	1969	4.5	42.9
	1.5	4.3		1.8	13.4		2.5	36.9
	1.8	18.0		9.1	32.3		1.7	18.7
	1.6	27.8		3.0	25.8		2.0	24.3
	1.2	17.0		6.5	28.9		2.0	17.4
	2.2	15.5	1969	2.5	8.6		4.2	18.9
	3.4	24.0		2.3	9.9		2.5	31.4
	1.4	14.8		1.6	14.1		4.0	33.1
	1.7	14.9		0.7	3.7		4.4	30.8
	7.4	30.4		0.5	2.3		2.5	16.1
	7.9	49.4		1.7	16.4		3.4	28.6
	2.8	29.4		8.9	33.8		2.2	19.9
	3.8	23.5		6.4	39.6		3.0	18.1
1967	1.4	9.7		3.0	20.2	1970	3.2	36.6
	3.9	22.3		2.3	26.3		2.0	22.8
	4.7	21.0		3.5	40.12		2.3	36.0
							1.2	7.9

APPENDIX C

DDT IN LAKE JOSEPH LAKE TROUT MUSCLE EXPRESSED AS ppm DDE, WET WEIGHT, 1968-1970

Year Collected	Weight (kg.)	DDE
1968	4.7	17.8
	2.3	15.6
	1.4	5.1
	3.5	44.8
	2.3	33.7
	2.0	17.5
	2.4	27.0
	0.7	27.2
	2.2	25.0
	1.4	10.5
1969	4.1	49.4
	5.5	19.7
	5.3	28.3
	2.4	9.8
	2.7	9.7
	3.6	15.3
	3.0	7.5
	2.3	7.6
	2.7	9.1
	3.0	9.1
	2.5	7.0
	1.8	6.1
1969	1.8	6.2
	4.5	15.1
	2.5	10.3
	3.6	12.2
	3.8	22.9
	2.3	6.5
	5.9	20.0
	2.3	10.5
	2.4	14.0
	4.5	11.4
	2.3	11.5
	2.5	7.3
	2.3	3.0
	3.7	20.7
	5.9	21.4
	3.6	12.4
	6.0	39.4
	3.7	13.0
	2.8	14.8
	4.5	29.9
	4.1	28.8
	6.7	14.9
1969	2.0	9.3
	3.2	8.2
	4.5	18.0
	3.8	10.4
	5.1	34.4
	6.1	25.3
	4.3	14.2
1970	5.2	31.1
	3.6	23.9
	2.5	20.5
	0.7	6.6
	3.0	12.8
	2.0	28.6
	0.9	4.8
	0.7	5.5
	2.0	13.6
	3.9	9.1
	3.4	13.9
	3.8	41.7
	2.6	12.9
	2.4	16.7
	2.8	26.0

APPENDIX D

MEAN DDT LEVELS IN MUSCLE OF LAKE TROUT AND SMELTS FROM NINE LAKES IN THE MUSKOKA AREA, EXPRESSED AS ppm TOTAL DDT WET WEIGHT

Lake	No. Samples	Lake Trout[a]	Smelts[b]
Fairy Lake	10	4.0	
	7		0.85
Lake Joseph	66	17.0	
	8		0.94
Lake Muskoka	66	35.1	
	39		1.9
Lake of Bays	12	2.8	
	2		1.04
Lake Rosseau	49	23.2	
	6		1.8
Lake Simcoe	5	6.5	
	10		1.1
Mary Lake	10	7.2	
	6		0.50
Penninsula Lake	10	2.9	
	2		0.36
Vernon Lake	10	1.47	
	4		0.28

[a] Lake Trout as DDE

[b] Smelts as total DDT

APPENDIX E

LAKE MUSKOKA FRY SURVIVAL STUDY, 1967 - 1968. TOTAL DDT IN INDIVIDUAL PARENTS, EGGS AND FRY AS EXPRESSED AS ppb WET WEIGHT.

Fish No.	Muscle	Gonad	Fertilized Eggs	FRY			
				Immediate Pre Swim-up	Died During Swim-up Period	Eight Week Post Swim-up	Percent Mortality At Swim-up Stage
1	53	4.8	10.6	9.84	6.75	1.65	65.8
2	128	13.5	13.3	12.85	8.16	3.37	44.6
3	62	11.1	13.1	11.48	10.38	2.37	55.4
4	80	8.7	13.3	13.06	12.67	3.24	79.2
5	70	6.9	8.9	13.04	9.20	1.15	46.9
6	76	6.8	10.7	13.72	13.37	3.74	63.8
7	66	7.1	14.2	16.61	15.14	3.50	74.5
8	82	14.8	7.4	10.63	13.26	4.65	50.0
9	53	15.7	11.9	11.29	9.28	2.08	89.8
10	57	5.4	9.6	15.43	12.96	2.57	46.8

APPENDIX F

MUSKOKA LAKES MONITORING STATIONS, 1970-1971 TOTAL DDT IN CLAMS, WATER AND SEDIMENT, EXPRESSED AS ppb

RIVER STATIONS

	May*		June		July		August		Sept.		Oct.	
Muskoka River	W	C	W	C	W	C	W	C	W	C	W	C
+Clams 1970	25			30		34		34		57	19	
+Clams 1971								18	35	24	25	26
**Sediment 1971									1.9			
Water 1971	0.020		0.013		0.013		0.009		0.009		0.008	
Load (lbs./mo.)	10		1.8		1.0		0.7		1.1		0.7	
Bala	W	C	W	C	W	C	W	C	W	C	W	C
+Clams 1970		25		29		169	27					21
+Clams 1971							46	49			55	34
**Sediments 1971									8.6			
Water 1971	0.040		0.017		0.013		0.013		0.010		0.008	
Load (lbs./mo.)	31		2.9		1.6		1.3		1.6		0.9	
Shadow River	W	C	W	C	W	C	W	C	W	C	W	C
+Clams 1970		25		45		166		13		68		35
+Clams 1971							33	12		35		15
**Sediments 1971									1.1			
Water 1971									0.009			
Load (lbs./mo.)									0.00002			

* Initial collection from Sandy Bay

W = Wild clams
C = Caged clams

+ Clam values represent composite analyses

** Sediments expressed in terms of dry weight

APPENDIX F

MUSKOKA LAKES MONITORING STATIONS, 1970-1971 TOTAL DDT IN CLAMS, WATER AND SEDIMENT, EXPRESSED AS ppb

LAKE STATIONS

	May*		June		July		August		Sept.		Oct.	
Sandy Bay	W	C	W	C	W	C	W	C	W	C	W	C
+Clams 1970	18								85			
+Clams 1971							40		33		24	
Port Carling	W	C	W	C	W	C	W	C	W	C	W	C
+Clams 1970		25		24		229		24		86		25
+Clams 1971							21	37		53	46	54
** Sediment 1971									23.1			
Water 1971									0.011			
Port Sandfield	W	C	W	C	W	C	W	C	W	C	W	C
+Clams 1970		25		33		47	57		89			21
+Clams 1971							81	41		32	46	30
** Sediment 1971									6.4			
Water 1971									0.008			

* Initial collection from Sandy Bay

W = Wild clams
C = Caged clams

+ Clam values represent composite analyses

** Sediments expressed in terms of dry weight

APPENDIX F

LAKE STATIONS Cont'd

	August		Sept.		Oct.	
Gravenhurst Deep	W	C	W	C	W	C
+Clams 1971						38
Gravenhurst Shallow	W	C	W	C	W	C
+Clams 1971				49		27
Milford Deep	W	C	W	C	W	C
+Clams 1971				56		41
** Sediment 1971			15.1			
Water 1971			0.042			
Milford Shallow	W	C	W	C	W	C
+Clams 1971	75			54	81	52
** Sediment 1971			56.4			
Port Cockburn	W	C	W	C	W	C
+Clams 1971	70			26		14
** Sediment 1971			3.2			
Water 1971			0.019			

W = Wild clams

C - Caged clams

+ Clam values represent composite analyses

** Sediments expressed in terms of dry weight

SB DDT residues in the Muskoka
952 Lakes system / Boelens, R.G.V.;
.D2 Rumsey, C.R.
B64 4620
1972